Sensory Integration

Theory and Practice

THIRD EDITION

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The third edition of this book, similar to the second, is dedicated to A. Jean Ayres, the inspiration for this text and the intervention and research it represents.

And to those who live with sensory integrative dysfunction, who are the best teachers.

ACKNOWLEDGMENTS

Whenever the two of us edit a textbook, it seems to involve moving around the world. This one was no exception. This time each of us moved to and/or from Australia (SJL moved both ways). Those moves undoubtedly contributed to the time it took for us to complete this edition—and also makes us very grateful to a number of people, without whom there would be no third edition.

First, we are indebted to the therapists, researchers, academics, and occupational therapy students in many countries of the world who read—and sometimes re-read—the first two editions of this book. They tell us that those books informed their practice—and they insisted we do a third. This third edition is the last for us. We are very grateful to Shelley Mulligan and Stacey Reynolds, who joined us in editing this time. We now pass the torch to them.

It almost goes without saying that the contribution of each author was critical but we would never want to be silent on this. This group of scholars is amazing—and amazingly patient. We are honored to have worked with them. We are also thankful to the numerous therapists who gave their time and resources to teach us about Jean Ayres' life and the history of sensory integration theory and practice. This information led to Chapter 2. Generous financial contributions from F. A. Davis—and a sabbatical from the University of Sydney—allowed us to travel all over the United States in search of their collective wisdom. We hope we have done a good job of interpreting what they said.

Tammie Fink, from the Sensory Gym in Hobartville, New South Wales, Australia, is responsible for many of the photographs in this edition. The photos bring the content to life. Our deep appreciation goes to Colleen Hacker for sharing Tammie's time, organizing children and families for the photo shoot, and of course getting those all-important photo releases signed. We can't even imagine a book without these "action" photos.

The reviewers of each chapter provided invaluable feedback. What they had to say was not always easy to hear—but it was always correct. We hope we have done justice to their comments.

Numerous colleagues and friends contributed in enormously important ways by reflecting on content, terminology, and interpretations of content. Judith Abelenda, in particular, not only spent countless hours discussing ideas, but she also made her home in Spain a writing retreat. We made a lot of progress in that week.

The folks at F.A. Davis stood by us through thick and thin. Christa Fratantoro, in particular, has been involved since the beginning and key to the last two editions. She is always our "go-to person" with any questions or needs. There are so many others that it would be impossible to list them without missing some. We are eternally grateful to all for your support.

Finally, as always, those closest to us, Rick Thornton and Ginny Deal, literally provided years of (nearly uncomplaining) support. Shelly's children, Hannah and Lucas Thornton, provided her cheering section, something that kept her going when deadlines loomed. We could not have thanked them enough—and we're pretty sure they would say we did not.

We have undoubtedly failed to mention some key players. That has more to do with failed memory than lack of significance of their contributions. We hope you will forgive us.

Anita Bundy
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FOREWORD

Janice P. Burke

"There is no substitute for a good idea" (Reynolds, 1971).

The rigor, passion, and vitality that A. Jean Ayres brought to addressing the problems of sensory integrative dysfunction in children is alive and well as proven by this third edition of Bundy and Lane's *Sensory Integration Theory and Practice.* Throughout the book, the authors exhibit current work that fully understands and implements contemporary education, research, and practice agendas related to sensory integration (SI). Each of the 23 chapters focuses on the importance of discoveries that advance the initial theory and application of SI first presented by A. Jean Ayres nearly 60 years ago.

The legacy of A. Jean Ayres is steeped in a tradition of inquiry and research. It is humbling to realize the profound effect that Ayres' foundational work still holds on the current day practice of occupational therapy. In the early 1960s, she had a remarkable sense of how a deep and detailed inquiry into neuroscience could provide a bridge to the field of occupational therapy when applied to individuals with SI problems. Her initial vision of what the marriage of these fields could yield has resulted in a sustained effort of thought and action that continues to propel us toward a research agenda for the 21st century (Chapters 15 and 16) and describe both assessment and intervention methodologies (Chapters 8 to 13).

Similar to Ayres herself, the authors in this book are intrigued and driven by the complicated questions posed by SI dysfunction. Their curiosity and good science expand her tradition of inquiry by asking difficult and probing questions. Both the questions and the resultant answers further inform the underlying theory (Part I), explicate SI disorders and their neuroscience basis (Part II), explore the current status of assessment and intervention (Parts III and IV), extend theory application (Part V), and provide case exemplars (Part VI).

The authors collected together in this edited text have made longstanding commitments to the full realization of Ayres' initial concepts and ideas for approaching assessment and intervention. Their chapters provide evidence of their ability to think scientifically and synthesize knowledge and understanding that readers will find useful as they define and implement the next wave of research. These authors exhibit the commitment and courage reflective of A. Jean Ayres. They continue the evolution of Ayres' work, particularly as evidenced in their consideration of broader applications of the theory (Chapter 16), inclusion of complementary approaches (Chapter 17), and application of SI principles beyond traditional diagnostic groups (Chapter 18).

The 1960s as a decade witnessed an explosion of conceptual and theoretical work across a wide swath of occupational therapy. Occupational therapy thinkers sought to import relevant ideas from neurobiology, kinesiology, psychoanalytic theory, and the social sciences. Ayres' contemporaries, including theoreticians such as Mary Reilly, Gail Fidler, Anne Mosey, Margret Rood, and Josephine Moore, to name a few, were eager to develop models that would guide clinicians to better assess and treat specific occupation-based problems.

These scholars recognized that occupational therapy was maturing as a profession, shifting away from a dependency on medicine and rehabilitation. Occupational therapy was ready to stand on its own two feet. Focused attention was needed to articulate theories with specific concepts and principles that would sharpen the understanding of the therapeutic value of an occupation-based approach. This was to distinguish the focus of occupational therapy as unique, and, as it turns out, lay the groundwork for what would become a research-based, evidence-generating, highly valued and widely recognized approach to remediating the problems of occupation. Using strategies from the social and hard sciences, they set out to understand and solve problems of occupation and the difficulties of fully participating in society.

Ayres, along with her contemporaries in neurobiology and education, were deeply involved in identifying, defining, and understanding children with visual and perceptual motor problems and learning difficulties. During the 1960s, they worked to develop ways for remediating occupational issues in both educational and clinical settings.

Ayres' perspective was authentic to its occupational therapy roots. It had a sharp focus on the needs of a special population of children and was designed as a bridge on the road to full participation. It provided the field with legitimate, science-based explanations for the use of specific occupational therapy approaches. Ayres drew the attention of occupational therapists concerned with children with neurologically based issues to the possibilities of a theory rooted in scientifically grounded principles. This theory was testable and subject to validation and proof. The path Ayres forged was rigorous and would have scholarly, and demanding, vistas.

I had the great fortune of studying at the University of Southern California with two incredible pioneers during this time of theoretical explosion in occupational therapy: A. Jean Ayres and Mary Reilly. Though their theoretical orientations were different, Ayres in the neurosciences and Reilly in social science, they both had a single-minded perspective of their subject matter that led to an unwavering commitment that set the stage for a theory-driven approach to assessment and intervention. Both had a foundational belief in the power of occupation. They employed similar strategies, based in evidence and observation, to test their ideas.

They surrounded themselves with students and scholars in graduate level education and worked to engage them in a path to become great thinkers. In this way, A. Jean Ayres and Mary Reilly planned to seed their ideas and create the next generation of leaders. All the students in their classrooms were able to benefit from the natural productivity that is inherent when one is curious, a student, and learning at the table of wonderful thinkers, mentors, and educators.

Paul Reynolds in *A Primer in Theory Construction,* his book on theory, wrote: "[T]he ultimate test of any idea is its utility in achieving the goals of science" (Reynolds, 1971).

I sat in graduate classes with both of them, on mats in Jean's clinic and at seminar tables in Mary's classroom. All present listened to the exquisite ideas they were developing. There I came to realize what was needed to reach the infinite possibilities and potentials that occupational therapy has to understand, articulate, and remediate problems of individuals as they move into a world of meaning and purpose.

What is especially intriguing about this period of theory development is to ask the question of why some theories, such as that of A. Jean Ayres, continued to evolve, prove their durability and applicability to current problems, and ask why some, even to this day, 60 years later, demonstrate their inherently sound foundation.

A. Jean Ayres had a good idea. This book is a testament to the durability of Ayres' initial idea and the science that followed and is an important milestone for the editors and authors who have made contributions to her legacy.

Reynolds, P. D. (1971). *A primer in theory construction*. Indianapolis, IN: Bobbs Merrill Educational Publishing.

PREFACE

More than a decade has passed since we published the second edition of *Sensory Integration: Theory and Practice.* A lot has happened in that time, and, as much as possible, we have tried to capture the evolution. We have made several notable changes from the second edition.

Ayres developed sensory integration (SI) theory in the 1960s at a time when the occupational therapy profession, struggling to gain credibility, embraced a medical model. Her driving force was to explain links between brain processing and observable behavior. Nonetheless, although participation in everyday activity was traditionally the core of occupational therapy, Ayres began her work in an era when many occupational therapists believed that changing body structure and function would translate automatically into improved function. Some therapists who employed SI therapy fell into that trap. What could be more seductive than changing the brain? But over-emphasis on changing the brain sometimes resulted in relegating occupation to the back seat. We now know that changing the brain matters, but only if those changes contribute to making everyday life easier and more meaningful—and that does not occur automatically. Publication of the *International Classification of Functioning Disability and Health (ICF)* has shifted the attention and beliefs of all health-care professionals toward activities and participation. In this third edition of *Sensory Integration: Theory and Practice,* we give greater prominence to SI in everyday life. Among other more subtle changes throughout the book, we expanded the chapter on SI and occupation from the second edition and placed it where it should be—near the front.

Ayres died in 1989 and she still is sorely missed. For many years, colleagues who had worked with her carried the torch that Ayres lighted. Through time, as might be expected, some of those colleagues shifted their focus to specific aspects of the theory. Ayres emphasized praxis and dyspraxia. She labeled “tactile defensiveness” and saw it as a reflection of poor sensory modulation. However, she did not live long enough to fully develop her explanations. In the ensuing decades, while the theory did not change fundamentally, the terminology associated with it morphed. At the same time, many occupational therapy educators relegated SI theory and therapy to continuing professional education, perhaps believing it was beyond that required for basic preparation of entry-level practitioners. All these factors seemed to conspire to make occupational therapists (and ultimately other professionals) increasingly unclear about the terminology associated with SI theory and what actually constituted sensory integrative therapy. Throughout this third edition of *Sensory Integration: Theory and Practice,* we have attempted to clarify the terminology and the principles of intervention. We also offer a new chapter (Chapter 3) tracing the history of the development of SI theory–with all its triumphs and dramas—from Ayres through to the present. We think that chapter makes a particularly good read.

Research evidence for both the theory and the intervention has risen to a higher level. Studies of SI now include government-funded randomized controlled trials (RCTs) as well as quasi-experimental, correlational, and descriptive studies that set the stage for additional RCTs needed to test the effectiveness of this complex intervention. In this third edition, we devote two chapters to that evidence. One chapter (Chapter 15) describes the clinically based research applicable in everyday practice. The second (Chapter 16) describes a growing body of basic research underpinning SI theory. We also have expanded the chapters on praxis and sensory modulation. Reflecting the explosion of research in the area, we also expanded the chapter on structure and function of the sensory systems (Chapter 4), augmenting it with some information on interoception, and added a separate chapter on sensory discrimination (Chapter 7).

Through time, we became increasingly aware of the need to illustrate the multiple complex aspects of assessment related to SI theory. In this third edition of *Sensory Integration: Theory and Practice,* we reintroduced a chapter describing the *Sensory Integration and Praxis Tests* (SIPT; Chapter 8); introduced an entire chapter on clinical observations (Chapter 9); and expanded the information on assessing without the SIPT into a chapter on its own (Chapter 10). We retained an updated and expanded version of the chapter on interpreting test results related to sensory integrative dysfunction, illustrating that process with multiple case examples (Chapter 11).

Since the second edition of *Sensory Integration: Theory and Practice,* Parham and colleagues developed and published a Fidelity Measure that operationally defines sensory integrative therapy. In providing clarification of what actually constitutes sensory integrative therapy, the Fidelity Measure has, arguably, had the greatest single effect on the intervention chapters. In this third edition, we label sensory integrative therapy as a direct intervention with particular characteristics. We offer a new chapter (Chapter 14) illustrating use of the Fidelity Measure as well as Miller and colleagues' STEP-SI and A SECRET models as a means for distilling theory in practice and making it more readily accessible. We retained the chapters describing the art and science of sensory integrative therapy (Chapters 12 and 13, respectively), but those chapters are so updated that they barely resemble their second edition predecessors.

In this third edition of *Sensory Integration: Theory and Practice, w*e clearly separate sensory integrative therapy from indirect approaches that often employ SI or related theories (i.e., coaching). We offer a new chapter on coaching (Chapter 17) that draws on, but is much expanded over, the second edition chapter that described use of SI theory as the basis for consultation in schools.

Recognizing the growth in thinking and options regarding occupational therapy intervention for children with motor coordination or sensory regulation issues, we offer a new case-based chapter (Chapter 22) in which we view intervention for a child with poor motor coordination, first through a sensory integrative lens and then through a Cognitive Orientation to daily Occupational Performance (CO-OP) lens. We retained and updated a chapter on sensory-based interventions often used as a complement to or instead of sensory integrative therapy (Chapter 18), including the Wilbarger Approach; the Alert Program; Interactive Metronome®; Astronaut Training; Infinity Walk Training; Therapeutic Listening®; Suck, Swallow, Breathe; and Aquatic Therapy. In an attempt to be clear about the relationship of each of these programs to SI, we analyzed each in terms of three factors: whether (1) the sensation provided is uni-modal or multi-modal; (2) the approach is responsive or prescribed; and (3) the setting in which it is delivered is traditional, nontraditional, or both. The authors of each program described the background, rationale, and relationship of the program to SI and occupation; benefits; and populations for which it is appropriate.

We have peppered all the chapters in this third edition with case examples. In addition, we have included several chapters entirely devoted to applying theory, assessment, or intervention principles in a case context. We retained and expanded a second edition chapter in which we illustrate the process of planning and implementing intervention for the child with sensory integrative dysfunction (Chapter 20) who was a case example in the interpretation chapter described earlier (Chapter 11). We complement that chapter with one comprising a case example of planning and implementing intervention for a child with autism spectrum disorder (Chapter 21).

The question of whether or not sensory integrative therapy is effective theory has always generated conversation and controversy both within and outside occupational therapy. In Chapters 15 and 16, we summarize the evidence from basic science and from clinical studies. We close this third edition with a chapter (Chapter 23) addressing the complex question of effectiveness explicitly. We remind readers that sensory integrative therapy comprises both art and science—and that to try to divorce one from the other is to destroy the essence of the intervention. Thus, researchers who have failed to consider both art and science have failed to test the effectiveness of sensory integrative therapy. Therefore, they cannot know whether or not it works.

We closed the Preface of the second edition with a comment that seems as apt for this edition as it was more than a decade ago:

> Sensory integration theory, as much as any theory in occupational therapy, depends on a partnership of art and science. Science gives sensory integration credibility; art gives it

> meaning. Toward a partnership of art and science, we offer these [new] works from a number of outstanding theorists, researchers, clinicians, and artists. Jean Ayres touched us all. We carry the torch that she passed to us at her death, fueling it with new perspectives and new knowledge.

At the request of several reviewers and to make this third edition more usable than previous editions for teaching, we added several pedagogical features. Among these: chapter objectives, periodic "Here's the Point" summaries, reflections of Practice Wisdom, brief summaries of relevant studies we have labeled "Here's the Evidence," and "enrichment" reading we have called "Where Can I Find More?" We hope these, and all the added features, will make learning and teaching this content easier and more enjoyable. Above all, we sought to create a text that students and practitioners *want* to read. We hope we have met our objective.

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CONTENTS

PART

I

Theoretical Constructs



CHAPTER 1

Sensory Integration: A. Jean Ayres' Theory Revisited

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Just as the continued production of research results in constantly changing neurological concepts, so also will [sensory integration] theory need to undergo frequent revision.

—A. Jean Ayres (1972b, p. ix)

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe the basic principles of sensory integration (SI) theory.
- ✔ Compare and contrast the various schematic representations of SI theory, realizing that they all illustrate the same theory.
- ✔ Describe a hypothesized relationship between constructs associated with SI theory and the Model of Human Occupation (e.g., volition; belief in skills).
- ✔ Compare and contrast two main categories of SI dysfunction: dyspraxia and sensory modulation dysfunction.
- ✔ Distinguish between two types of dyspraxia (i.e., deficits in bilateral integration and sequencing, somatodyspraxia) and two types of sensory modulation dysfunction (i.e., over-responsivity; under-responsivity) in terms of hypothesized sensory bases and overt indicators.
- ✔ Identify assumptions and boundaries of SI theory and SI intervention.

Purpose and Scope

A. Jean Ayres' sensory integration (SI) theory has sparked more research, had a more marked effect on, and generated more controversy than any other theory developed by an occupational therapist. Originally, Ayres, an occupational therapist with advanced training in neuroscience and educational psychology, developed SI theory to explain relationships between deficits in interpreting sensation from the body and the environment and difficulties with academic and motor learning.

Ayres' knowledge of neuroscience led her to *observe* deficits in learning and behavior and *hypothesize* that those deficits were the result of poor processing of sensation in the central nervous system (CNS). In other words, she hypothesized relationships among areas of the CNS and various behavioral constructs. Although knowledge of neurophysiology has grown exponentially in the intervening years, many of the links that Ayres hypothesized have been upheld. (See Chapter 4, Structure and Function of the Sensory Systems, and Chapter 6, Sensory Modulation Functions and Disorders.) Some, of course, remain hypotheses. (See Chapter 23, Is Sensory Integration Effective? A Complicated Question to End the Book.)

Drawing from her doctoral study in educational psychology, Ayres developed tests to measure the constructs associated with SI theory and examine their relationships. Many other researchers have since replicated and extended Ayres' research—for the most part upholding her findings. (See also Chapter 15, Advances in Sensory Integration Research: Clinically Based Research.)

Based on the hypothesized relationships among theoretical constructs, Ayres developed SI therapy. When she observed changes in learning and behavior in children who received the intervention, she *hypothesized* that those improvements reflected improved SI and enhanced neural functioning. Ayres (1972a, 1976) then tested the **effectiveness** of SI therapy through research, supporting her hypotheses. Several other researchers subsequently tested the effectiveness of SI therapy, some supporting the intervention and others questioning its effectiveness. We summarize some of that research in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research) and reflect on the mixed findings in Chapter 23 (Is Sensory Integration Effective? A Complicated Question to End the Book).

Ayres died more than 30 years ago. Although numerous authors have proposed alternative terminology and represented SI theory in different ways, the theory remains remarkably similar to that which Ayres proposed. In this chapter, we demonstrate the continuity of the theory.

SI therapy, too, bears marked similarity to that which Ayres implemented in her own clinic. In creating a **fidelity** measure, Parham and colleagues (2011) clarified the criteria for SI therapy. Those criteria are now applied in, and to, research and practice. (See Chapter 14, Distilling Sensory Integration Theory for Use: Making Sense of the Complexity.) Research, although not unequivocally demonstrating the effectiveness of the therapy, has made great strides in that direction. The return to studying SI therapy in its entirety—art and science—has made important contributions to demonstrating effectiveness.

This chapter provides an introduction to the theory now known as Ayres Sensory Integration® (ASI). We list the constructs associated with the theory and illustrate their hypothesized relationships. We describe two major categories of **SI dysfunction: dyspraxia** and **sensory modulation dysfunction.** Within each of those categories, we define different subtypes: for dyspraxia, difficulties with vestibular bilateral integration and sequencing (VBIS) and somatodyspraxia; for sensory modulation dysfunction, **over-responsivity** (i.e., sensory defensiveness, gravitational insecurity, and aversive responses to movement) and **under-responsivity.** We offer a model expanding Ayres' conceptualization of SI to explicitly include psychosocial sequelae. We compare schematic representations created by numerous authors illustrating SI theory in different ways. We describe the boundaries of the theory and intervention with regard to the populations to whom it can be applied and the nature of the intervention.

In this chapter, we do *not* attempt to explain the neurological underpinnings of SI. Neither do we critique the assessments associated with the theory, describe the intervention in detail, or discuss the research examining its effectiveness. We cover all that in chapters comprising the subsequent seven sections: (1) Theory; (2) Sensory Integrative Dysfunction and Hypothesized Neuroscience Underpinnings; (3) Assessment; (4) Intervention; (5) Research; (6) Complementing and Extending the Theory and Its Application; (7) Applications.

Sensory Integrative Dysfunction: Illustrating the Reasoning

CASE STUDY ▪ JOSHUA

Joshua has poor gross motor coordination and difficulty learning new motor tasks. Some of the other children in his class play baseball on a local team, but Josh cannot catch, throw, or bat nearly well enough to be included. Although he rides his bicycle everywhere, learning to ride took more effort for him than for others. However, he prefers riding the bicycle to a skateboard, which he found "just too hard."

On standardized testing, Josh had difficulty discriminating touch, imitating postures, and reproducing movement sequences that involve coordinated use of both sides of the body. On standard clinical observations, he had poor posture and ineffective equilibrium reactions.

Josh has no evidence of peripheral nervous system or CNS damage and he is of average intelligence. Therefore, because empirical evidence consistently links diminished ability to discriminate body sensations with poor **praxis,** we speculated that Josh's problems were caused by sensory integrative dysfunction. We further speculated that sensory integrative therapy would improve Josh's ability to integrate sensation and plan actions. Sensory integrative therapy involves active engagement in activities providing a "just right challenge" and inherent opportunities to take in enhanced tactile, vestibular, and proprioceptive sensations.

We hypothesized that if, after a trial of intervention, Josh's coordination seemed better, we would attribute the changes to improved SI and motor planning. Even without the ability to directly observe CNS processing, we would also hypothesize that improvements in processing were present.

Introduction to Sensory Integration Theory

Ayres (1972b) defined *sensory integration* as "the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment" (p. 11). Ayres focused on the vestibular, proprioceptive, and tactile systems—perhaps because she believed that researchers had ignored them in favor of the visual and auditory systems. Although the vestibular, tactile, and proprioceptive systems take center stage in Ayres' theory, she did not discount the importance of the visual and auditory systems. In fact, Ayres (1972b, p. 73) indicated that "the human being is not only a highly visual animal, he is . . . so conscious of being visual that the very word 'perception' is usually construed to mean *visual* perception" (italics added). Nonetheless, Ayres felt that visual perception was an end product and that the vestibular system was its main foundation (Sieg, 1988). Similarly, Ayres studied the effect of sensory integrative therapy on children with auditory-language difficulties, believing that the relationship between the vestibular and auditory systems meant they might be good candidates for the intervention.

Although Ayres (1979) included the auditory and visual systems in her schematic representations of SI theory (see, for example, Fig. 1-3), she never fully fleshed out their contributions to the theory. Currently, therapists implementing sensory integrative therapy often *also* prescribe programs such as Interactive Metronome® and Therapeutic Listening® that target the auditory system (see Chapter 18, Complementary Programs for Intervention). Similar to Ayres, we include the visual and auditory systems in the model we use throughout this text (Fig. 1-6) and in Chapter 4 (Structure and Function of the Sensory Systems). However, even now, SI theory has not expanded to embrace these systems fully.

PRACTICE WISDOM

Theory Is Not Fact

SI is a *theory* of brain–behavior relationships. Theories are *provisional* statements that help to

- *Explain* why people behave in particular ways
- *Develop intervention* to ameliorate related difficulties
- *Predict* how behavior will change because of intervention

Postulates of Sensory Integration Theory

SI theory is not only about dysfunction and intervention. It also postulates that efficient SI underlies learning. Thus, SI theory comprises three broad postulates. The first describes SI and learning. The second defines sensory integrative dysfunction. The third guides intervention.

1. Learning, in the broadest sense, is dependent on the ability to process and integrate sensation and use it to plan and organize behavior. This postulate has given rise to the constructs included in the theory and described throughout this book.
2. A decreased ability to process and integrate sensation may result in difficulty producing appropriate actions, which, in turn, may interfere with learning and behavior. This postulate has given rise to standardized tests reflecting the various constructs of the theory. See Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests) and Chapter 9 (Using Clinical Observations within the Evaluation Process) and also Dunn (2014), and Parham, Ecker, Kuhaneck, Henry, and Glennon (2010).

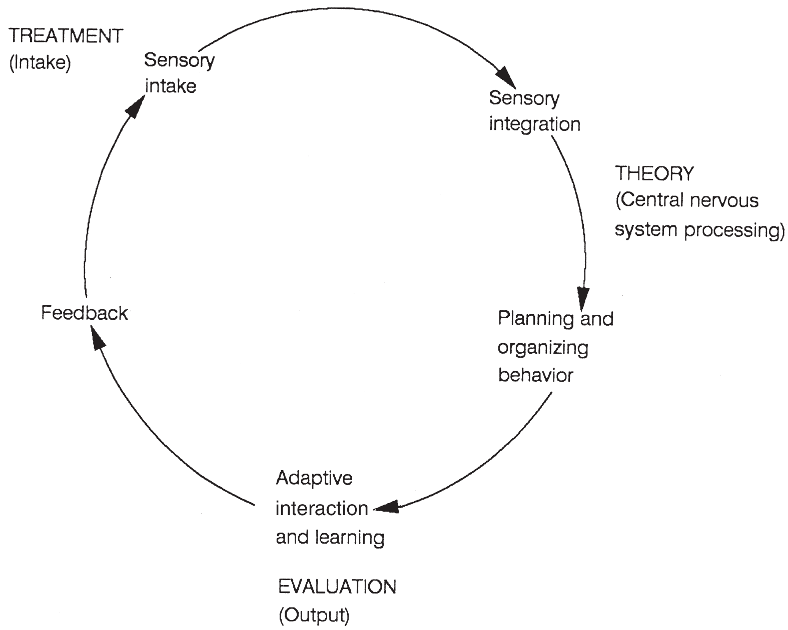


FIGURE 1-1 A schematic representation of the learning component of SI theory.

3. Sensations generated and integrated in the context of a "just right challenge" contribute to improved CNS processing, thereby enhancing learning and behavior. This postulate has given rise to sensory integrative therapy. See also Chapter 12 (The Art of Therapy) and Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory).

Illustrating Sensory Integration Theory

Schematic representations are a good way of portraying the essence of a theory by displaying the relationships among the constructs. Creators of schematics select the constructs and illustrate their relationships in the ways that make sense to them and emphasize the points they find most salient. Thus, different authors often represent the same theory in slightly different ways.

Sensory Integration Theory and Learning

In Figure 1-1, we depict the contribution of SI theory to learning, very simplistically, as a circular process. The process begins with taking in sensation and culminates with sensory feedback. Feedback, together with *new* sensory intakes, in turn, initiate a new cycle of learning. In Figure 1-2, we broaden the schematic shown in Figure 1-1, overlaying the dysfunction, evaluation, and intervention postulates of SI theory on the intake, processing, and feedback circle.

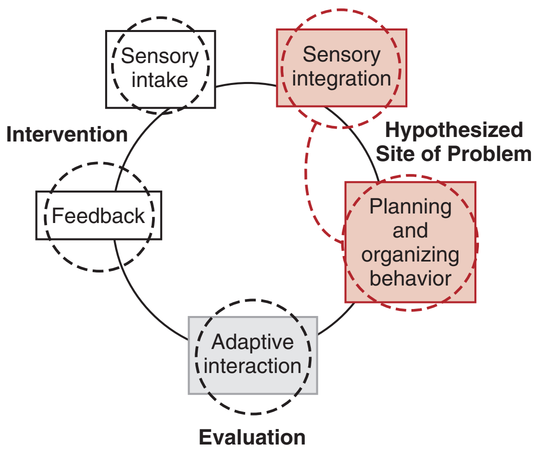


FIGURE 1-2 A simple representation of the three postulates of SI theory.

Ayres (1979) focused on the contribution of SI to learning in the complex schematic representation shown in Figure 1-3. At the far left of the schematic, she listed all the senses (i.e., the

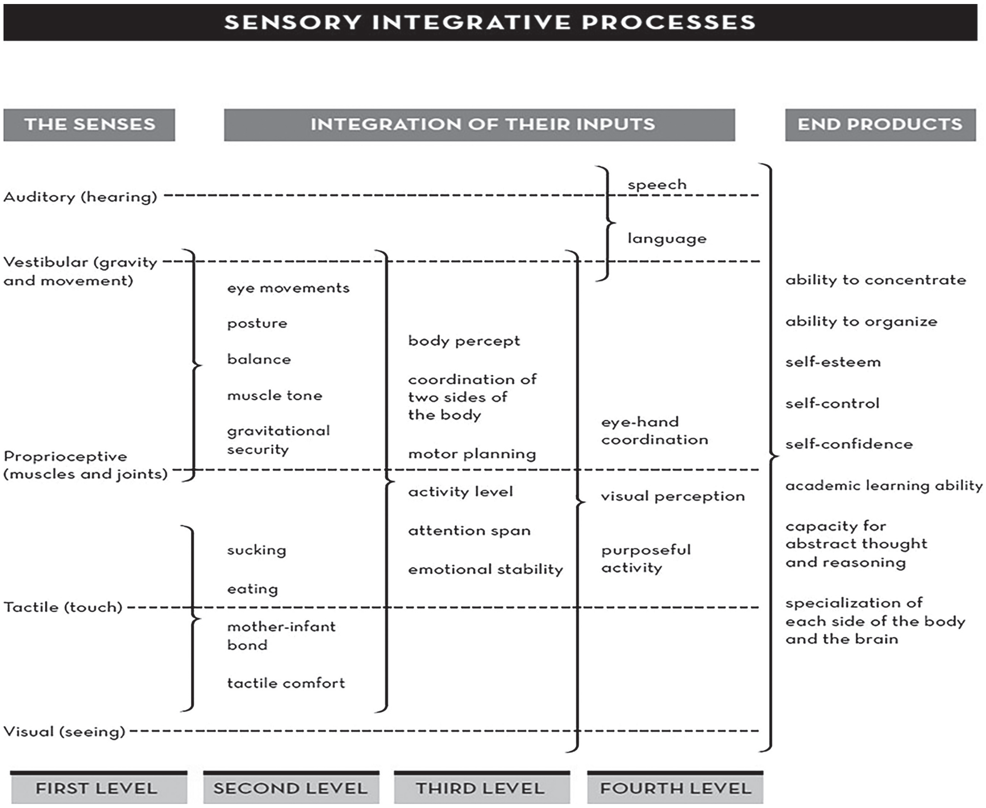


FIGURE 1-3 Ayres' (1979) schematic representation of SI theory. *Sample items of the Sensory Integration and the Child, 25th Anniversary Edition copyright © 2005, by Western Psychological Services. Reprinted by permission of the publisher, Western Psychological Services. Not to be reprinted in whole or in part for any additional purpose without the expressed, written permission of the publisher (rights@wpspublish.com). All rights reserved.*

sources of sensory intake and feedback). Moving to the right, Ayres described increasingly complex outcomes related to efficient processing of sensation, labeling them "integration of inputs" and "end products." On the schematic, Ayres used brackets to associate the outcomes with relevant senses. Her schematic clearly shows the hypothesized contributions of the vestibular, proprioceptive, and tactile systems to learning but also includes the auditory and visual systems. The further to the right that one moves on Figure 1-3, the more distant the inputs from the simple sensations and the more that other factors potentially come into play. For example, ability to concentrate, located at the far right, depends on all the senses, as shown by the bracket. But ability to concentrate also depends on many other factors (e.g., cognition, interest, and environment).

Sensory Integrative Dysfunction

In Figure 1-4, we present a simple schematic representation of the two major categories of sensory integrative dysfunction: sensory modulation dysfunction and dyspraxia. As the diagram shows, individuals with sensory integrative dysfunction can have one or both types of dysfunction. This simple representation is a broad-brush illustration of sensory integrative dysfunction, showing the big categories but lacking detail about subcategories.

Miller and her colleagues (Miller, Anzalone, Lane, Cermak, & Osten, 2007) also created a schematic representation of sensory integrative dysfunction, which they referred to as a "nosology" (i.e., a system for classifying diseases). However, rather than use the label *sensory integrative dysfunction,* they coined the term ***sensory***

processing disorder. (See Fig. 1-5.) The constructs included in the nosology are remarkably similar to those that Ayres described in SI theory and, in fact, were determined largely based on Ayres (1972c, 1989) and other researchers (e.g., DeGangi, 2000; Dunn, 2001; Mulligan, 1996, 1998, 2000) who sought to build on Ayres' findings (Miller et al., 2007). The nosology confirms that it is possible to change a name without changing the basic theory.

Miller et al.'s (2007) nosology is simple and, in many ways, elegant. However, one difficulty with the nosology is that it fails to depict explicit links between sensory systems and behaviors. For example, the links between posture and the vestibular and proprioceptive systems, or between praxis and aspects of sensory **discrimination,** seen in Ayres' model are not included in Miller et al.'s nosology.

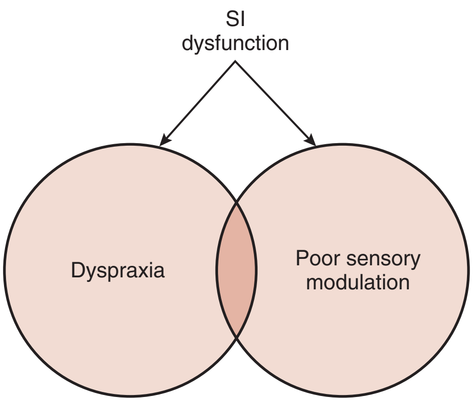


FIGURE 1-4 Simplified representation of manifestation of SI dysfunction.

We created the schematic shown in Figure 1-6 to represent hypothesized relationships between the sensory systems and behavioral manifestations of sensory integrative dysfunction. Although this schematic focuses on dysfunction rather than function, Figure 1-6 is organized similarly to Ayres' schematic (Fig. 1-3). However, Figure 1-6 is read outward from the center column where CNS processing of sensation is depicted. Indicators of poor SI and praxis are shown on the right, and indicators of sensory modulation dysfunction appear on the left. This enables us to show the two manifestations of sensory integrative dysfunction: dyspraxia and sensory modulation dysfunction, and their relationship to the processing of sensation. As shown in Figure 1-4, an individual can have one or both of these broad categories of sensory integrative dysfunction.

In Figure 1-6, the closer the columns are to the center, the more direct the relationship with processing of sensation. For example, postural ocular control appears in the column just to the right of the center column (i.e., on the praxis side). Processing of vestibular and proprioceptive sensation is related directly to postural ocular control. In fact, in SI theory, a meaningful cluster of postural ocular reactions is regarded as a direct manifestation of vestibular proprioceptive processing. (See also Chapter 4, Structure and Function of the Sensory Systems, and Chapter 9, Using Clinical Observations within the Evaluation Process.) In other words, although we cannot see poor vestibular proprioceptive processing, we see a

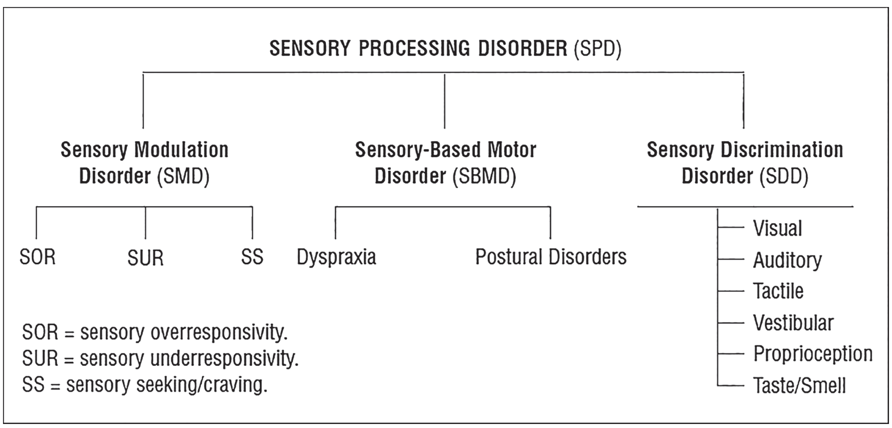


FIGURE 1-5 Miller et al.'s (2007) nosology of sensory processing disorders. *Republished with permission of AOTA, from Concept Evolution in Sensory Integration: A Proposed Nosology for Diagnosis by Lucy Jane Miller, Marie E. Anzalone, Shelly J. Lane, Sharon A. Cermak, and Elizabeth T. Osten; volume 61, March/April 2007.*

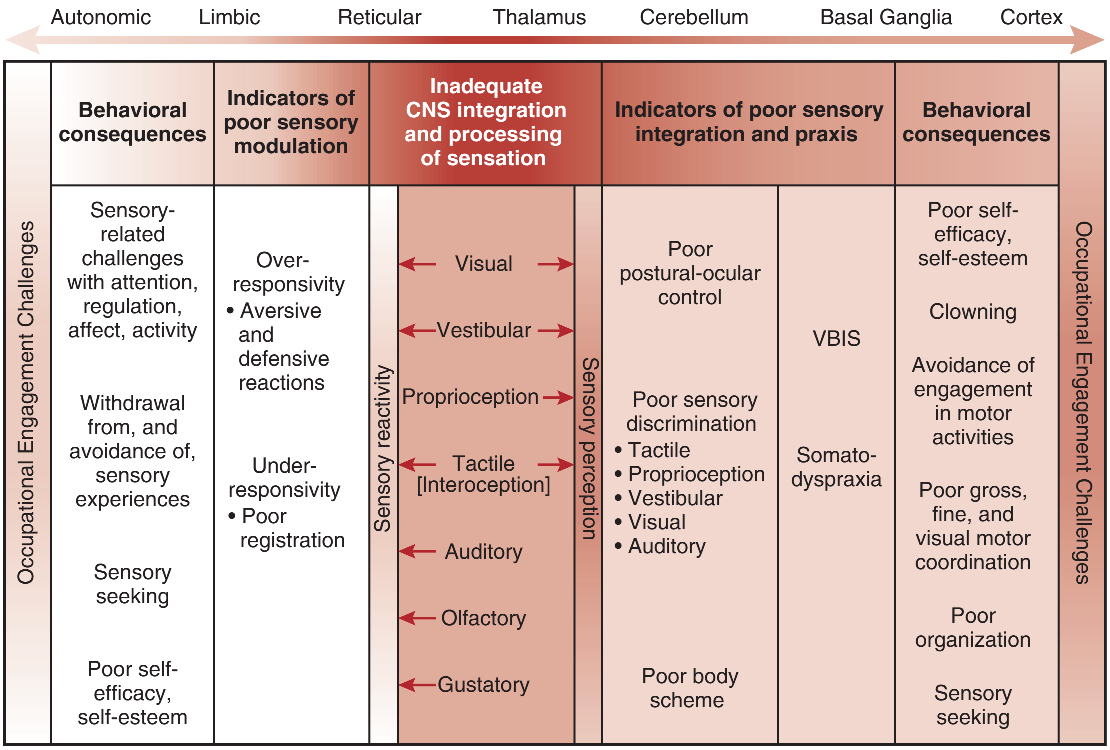


FIGURE 1-6 Complex schematic representation of sensory integrative dysfunction.

meaningful cluster of behaviors that define poor postural control and we interpret these behaviors as reflecting difficulties with processing vestibular proprioceptive sensations. Similarly, **body scheme** (i.e., the sense of where body parts are in relation to one another) is tied directly to the processing of sensation although it is not readily observable. We interpret actions in which children seem unaware of the relationship of body parts to one another or to objects as reflecting poor body scheme.

As we move further to the right side on Figure 1-6, similar to Ayres' schematic (Fig. 1-3), the columns contain constructs tied less directly to processing of sensation. Those constructs are complex and many factors contribute to their quality. Deficits in praxis (i.e., VBIS, somatodyspraxia) comprise one column. The columns further to the right contain abstract constructs common in individuals with poor praxis but which, *by themselves,* are not indicators of sensory integrative dysfunction: poor self-efficacy, avoidance, and other similar items. That is, many factors besides sensory integrative dysfunction can cause poor self-efficacy, and so on.

In Figure 1-6, indicators of poor sensory modulation appear in the columns on the left. The closer the columns to the center, the more directly they reflect processing of sensation. Each sensory system may be associated directly with over- or under-responsivity. The constructs that appear further to the left (e.g., sensory-related challenges with attention, withdrawal, seeking, and, ultimately, challenges with occupational engagement) are common in individuals with sensory modulation deficits but they are complex and influenced by multiple factors.

Challenges with occupational engagement comprise the columns at the farthest left and the farthest right. Although some of the labels within those columns are the same, we expect the nature of the challenges that result from poor modulation to differ from those related to dyspraxia. For example, both groups of children might have difficulty with dressing or completing school work. The challenges for a child with poor modulation might stem from difficulties maintaining attention, whereas those for a child with dyspraxia would reflect the motor challenge. Similarly, both groups might have difficulty with self-esteem or self-efficacy. Children with a sensory modulation disorder, for example, may have decreased self-esteem because they are often in trouble for misbehaving, and may come to see themselves as bad or worthless (i.e., low self-esteem) or not as capable as others (i.e., low self-efficacy). Children with dyspraxia, on the other hand, may experience low self-efficacy because they perceive their motor skills as inferior to those of peers and low self-esteem because they believe that people with poor motor skills are less valuable than people with good motor skills. Sensory seeking also appears on the extremes of both sides of the model as a behavior associated with sensory under-responsivity or poor body scheme, when a child seeks unusually great amounts of sensation to augment the sense of where his or her body parts are in space.

HERE'S THE POINT

- The initial model of SI was developed by A. Jean Ayres, and it depicts SI function.
- The current model, used throughout this text, is one depicting two broad categories of dysfunction, dyspraxia and sensory modulation disorders.

The Constructs

The two primary categories of sensory integrative dysfunction, dyspraxia and sensory modulation dysfunction, deserve some further explanation. In Table 1-1, we briefly define and describe the constructs associated with each category.

TABLE 1-1 Constructs Associated with Sensory Integrative Dysfunction

CONSTRUCTS ASSOCIATED WITH DYSPRAXIA			
Construct	**Brief Description**	**Hypothesized Cause**	**Related Chapters**
VBIS	Difficulty planning and using the two sides of the body in a coordinated fashion and sequencing anticipatory (feedforward-dependent) motor actions (e.g., Schmidt & Lee, 2011)	Poor central processing of vestibular and proprioceptive sensations, seen as poor postural-ocular control	5: Praxis and Dyspraxia 9: Using Clinical Observations within the Evaluation Process; for assessment of bilateral coordination and projected action sequences
Somatodyspraxia	More severe form of dyspraxia than VBIS	Deficits in body scheme resulting from poor sensory discrimination, esp. tactile, proprioceptive, or vestibular	5: Praxis and Dyspraxia; for a thorough description of somatodyspraxia

Poor postural-ocular control	Basis for VBIS and sometimes for somatodyspraxia. Seen in
	• Low extensor muscle tone
	  ◦ Decreased ability to assume anti-gravity postures
	  ◦ Poor proximal stability
	  ◦ Poor equilibrium
	• Depressed postrotary nystagmus
		Outward manifestation of deficits in vestibular or proprioceptive processing	7: Sensory Discrimination Functions and Disorders
			9: Using Clinical Observations within the Evaluation Process

Poor body scheme	Deficits in the internal map representing the spatial relationship of body parts	Poor discrimination of tactile and proprioceptive (i.e., somatosensory) sensations	4: Structure and Function of the Sensory Systems 5: Praxis and Dyspraxia
Poor sensory discrimination	Poor interpretation of the spatiotemporal characteristics of sensation (i.e., Where? How intense? Direction of movement?)	Poor CNS processing of inputs in any sensory system	4: Structure and Function of the Sensory Systems 7: Sensory Discrimination Functions and Disorders

Dyspraxia

In sensory integrative theory, dyspraxia refers to difficulty planning new movements stemming from poor body scheme that, in turn, results from deficits in processing vestibular, proprioceptive, or tactile sensation. Ayres (1985) described **ideation** (i.e., the formation of ideas for action) as a cognitive component of praxis. Two decades later, May-Benson (2001, 2005; May-Benson & Cermak, 2007) explored ideation and sensory-integrative-based dyspraxia more fully. And although it seems clear that some children with dyspraxia, particularly those with more severe forms, have difficulty with ideation, to date no researchers have included data reflecting ideation in a factor analytic study examining its relationship to other constructs of SI theory or situating it within types of dyspraxia.

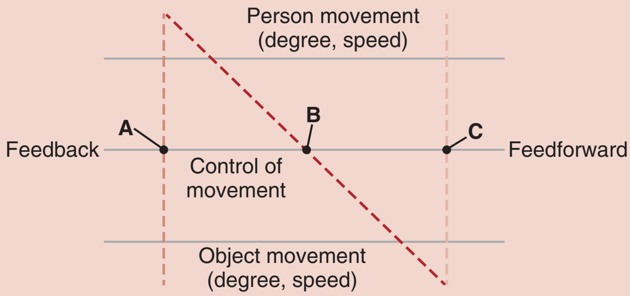
In this text, we describe two types of dyspraxia: VBIS dysfunction and somatodyspraxia. As you see in Table 1-1, we hypothesize that VBIS is a less severe practic deficit than somatodyspraxia. We base that on research suggesting that praxis is a single construct (e.g., Lai, Fisher, Magalhaes, & Bundy, 1996; Mailloux et al., 2011; Mulligan, 1996, 1998, 2000) and on extensive practical experience. The argument for praxis as a single construct with VBIS as less severe and somatodyspraxia as more severe is logical given that children with somatodyspraxia have difficulty with both simple (feedback-dependent) and complex (feedforward-dependent)

PRACTICE WISDOM

When actions are controlled by feedback, they can be adjusted in response to that feedback. For example, when a child stops a ball with his or her foot before kicking it, the child can adjust the direction of the kick in response to the tactile and proprioceptive feedback received through his or her foot and leg. When movements are under feedforward-control, a child must move his or her hand or foot to a particular location *before* the object on which he or she will act arrives at that location. Feedforward-dependent actions cannot be adjusted after the command to execute the movement has been issued. So, the child who runs to meet the ball and kicks it in mid-stride cannot adjust the kick once it has been initiated. Not surprisingly, many feedforward-dependent actions are bilateral.

Sugden and his colleagues (Henderson & Sugden, 1992; Keogh & Sugden, 1985) offered a simple model for gauging the degree to which an action is under relative feedback or feedforward-control. These investigators indicated that control (feedforward vs. feedback) is a function of movement of both the child and any object(s) on which the child is acting (e.g., a ball). The more or the faster that the child or an object moves, the more control must be feedforward-dependent. Feedforward-dependent actions are more difficult than feedback-dependent actions. Here is an adapted version of Sugden's model.

In the figure, a line connecting points representing relative movement of a child and an object passes through a point on the line illustrating the degree to which the action is feedforward- or feedback-dependent. Clearly, this diagram is overly simplistic but it can be useful for understanding the **motor planning** difficulties of children with dyspraxia and for grading the difficulty of intervention activities.



Control of movement as a function of the mover and the object.

HERE'S THE EVIDENCE

For more than four decades, factor analyses of data from the Sensory Integration and Praxis Tests (Ayres, 1989) and its precursor, the Southern California Sensory Integration Tests (Ayres, 1972c), along with the Southern California Postrotary Nystagmus Test (Ayres, 1975), yielded patterns of test scores that describe sensory-integrative-based dyspraxia (Ayres, 1965, 1966a, 1966b, 1969, 1972d, 1977, 1989; Ayres, Mailloux, & Wendler, 1987; Mailloux et al., 2011; Mulligan, 1996, 1998, 2000). Ayres found that tests requiring bilateral integration, sequencing of finger and arm movements, and postural control typically loaded together on a factor known most recently as VBIS.[1] She also found that tests of imitation, oral praxis, tactile discrimination, and proprioception consistently loaded together; she called these somatopraxis. More recent researchers (Mailloux et al., 2011; Mulligan, 1996, 1998, 2000) found slightly different loadings of tests, although they found relationships among all factors. Mailloux et al. (2011) labeled their practic factors "Visuodyspraxia and Somatodyspraxia" and "Vestibular and Proprioceptive Bilateral Integration and Sequencing" (VPBIS). VPBIS contained loadings of both sensory and motor tests, but Visuodyspraxia and Somatodyspraxia did not. Mulligan (1998) similarly failed to find loadings of sensory and motor on the same factor. She concluded, cogently, that it is best always to describe the nature of a particular child's sensory integrative dysfunction. For example, a child with both dyspraxia and poor somatosensory discrimination is best described using both labels.

[1]VBIS has been known by several names: for example, just BIS, and Postural and Bilateral Integration (PBI).

actions whereas children with VBIS primarily have difficulty with the high-level feedforward-dependent tasks.

Sensory Modulation Dysfunction

The concepts of sensory modulation and sensory modulation dysfunction are somewhat abstract. Although the term *modulation* is familiar to many therapists, its precise meaning can be somewhat elusive. Ayres (1979), who first applied the concept to SI theory, defined *modulation* as the CNS's regulation of its own activity. Engineers liken modulation to tuning a radio to the amplitude and frequency of the sound waves emitted by a station. When the amplitude and frequency detected by the radio tuner match those of the station's sound waves, the station comes in clearly. However, when the tuner is not properly modulated, the radio is rendered ineffective. Individuals who have difficulty modulating sensation behave as though the amplitude of their response is consistently greater or less than that of most individuals, decreasing the effectiveness of their performance. This is illustrated in Figure 1-7.

In this text, we describe two types of sensory modulation dysfunction (i.e., over-responsivity and under-responsivity). The responses of a child who is overly responsive to sensation are of greater amplitude than expected. We label over-responsivity to tactile or auditory sensations as defensiveness (i.e., a fight-or-flight reaction) and to vestibular sensation as gravitational insecurity

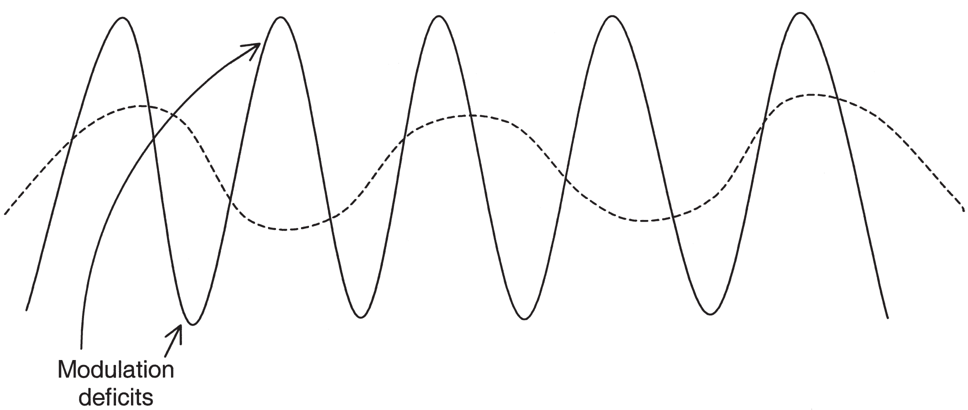


FIGURE 1-7 Schematic representation of modulation and modulation deficits.

(i.e., fear) or aversive (i.e., autonomic) responses. Under-responsivity refers to reactions of less-than-expected amplitude. We can see them in any sensory system. It is worth noting that under-responsivity can be difficult to differentiate from poor discrimination. Clinically, therapists have also identified *fluctuating responsivity*, a term used with children whose responses are sometimes greater-than-expected and sometimes less-than-expected in any sensory system or across systems.

Review Table 1-1 for a description of the major constructs associated with SI theory. We begin with indicators of poor SI and praxis and then move to indicators of poor sensory modulation.

HERE'S THE POINT

- Problems in sensory discrimination may lead to poor postural-ocular control and poor body scheme which, in turn, contribute to dyspraxia (i.e., VBIS and somatodyspraxia).
- Sensory modulation dysfunction is seen as persistent over- or under-responding to sensations.

HERE'S THE EVIDENCE

Statistical evidence of sensory modulation dysfunction was not available until the 1990s when formal tests were first developed. Before that time, a diagnosis of sensory modulation dysfunction was based on observation and informal interview. For example, Ayres' (1972c, 1989) statistical analyses included only her observation of a child's discomfort in response to being touched during testing, which she labeled tactile defensiveness. Now, standardized tests exist that, although not purely measures of modulation or even of dysfunction, contain items reflecting processing vulnerabilities (e.g., under- and over-responsiveness, sensory seeking) in multiple sensory systems. Identification of fluctuating responsivity across sensory systems requires examining and comparing scores for sensory domains. We do not have a standardized test that clearly identifies fluctuating responsivity within a single sensory system.

Two "families" of tests are used most commonly: (1) *Sensory Profile 2* (Dunn, 2014) with versions for infants, toddlers, and children, and the *Adolescent/Adult Sensory Profile* (Brown & Dunn, 2002) and (2) *Sensory Processing Measures* (Parham, Ecker, Kuhaneck, Henry, & Glennon, 2010). Factor analytical studies of data from these various parent- and self-report measures have revealed patterns of sensory modulation or sensory modulation dysfunction (e.g., Dunn, 1994, 2014; Dunn & Brown, 1997; Dunn & Westman, 1997). More recently, researchers (e.g., A. E. Lane, Young, Baker, & Angley, 2010; S. J. Lane, Reynolds, & Dumenci, 2012; S. J. Lane, Reynolds, & Thacker, 2010; Reynolds, Bendixen, Lawrence, & Lane, 2011; Reynolds, Lane, & Thacker, 2011) have paired parent and self-report measures with behavioral tests and physiological measures in an attempt to gain further understanding of sensory modulation and sensory modulation dysfunction.

Uniting Sensory Integration with Psychosocial Constructs

Kielhofner and Fisher (1991) felt that viewing poor self-esteem as simply a byproduct of sensory integrative dysfunction failed to consider sufficiently how a child's view of self emerges and how self-perception influences that child's behavior. They indicated that psychosocial events are at least as complex as SI and pointed to the need for a sophisticated view. Kielhofner and Fisher illustrated the complexity of the relationship between sensory integrative dysfunction and common psychosocial sequelae with the story of Joe, a 9-year-old boy up to bat in a Little League practice session.

CASE STUDY ■ JOE

Joe's brain appeared to lack the ability to integrate sensation from his body and the environment effectively and efficiently. His difficulty integrating sensation seemed to explain his struggles with planning and producing motor actions that caused him to appear clumsy. But what does SI theory tell us about how or what Joe felt? Joe deeply wanted to play baseball well. But he felt extremely frightened as the pitcher got ready to throw the ball. Joe knew the challenge was to meet the pitched ball with the swing of his bat, but he did not know how to do it. He had little awareness of how it should feel to swing the bat and hit the ball. What he *could* feel was the eyes of his peers bearing down on him as the ball raced in his direction. Joe became increasingly aware of an aching feeling in the pit of his stomach; his anxiety was acute and distressing. Joe had a deep and pervasive feeling that he was "no good" and that he would not be able to hit the ball.

Joe's emotional state manifested as over-arousal and anxiety. As the ball approached, it seemed to disappear from sight and he was unaware of his relationship to it in time and space. He swung the bat almost in self-defense and in the vain hope that somehow it would connect with the ball. But he missed widely and the whole performance had a tragicomic appearance. A chorus of jeers and laughter from his peers painfully drove home his error. And this was not a new experience; Joe's discomfort with using his body for any of the coordinated actions required in sports was familiar to him. The harder he tried, the more difficult it was to get things right. For Joe, not being able to execute motor actions as he wished and feeling uncomfortable around peers as his performance missed the mark was a familiar and uncomfortable experience.

In Joe's case, we may speculate that inefficient processing of sensation was responsible for the quality of his motor performance. But we can hardly argue that Joe's difficulty processing sensation, and nothing else, caused his poor performance. Clearly, Joe's psychological state had something to do with how he performed. What went on as Joe missed the ball was much more than just a case of poor SI and uncoordinated motor behavior. Neither Joe's performance nor his experience could be captured adequately by explanations grounded only in SI. Rather, the psychosocial experience was an equally important part of what Joe did and felt.

Kielhofner and Fisher (1991) cited DiJoseph (1982) in pointing out that when a therapist focuses only on SI, paying little attention to psychosocial phenomena—or vice versa—intervention is necessarily incomplete. A therapeutic approach that appreciated how they were interrelated had obvious advantages over a narrow or fragmented approach. Thus, in an attempt to address the very real concerns that Kielhofner and Fisher discussed, Fisher and Murray (1991) adopted a spiraling model often used in occupational therapy theory. Their Spiral Process of Self-Actualization (see Fig. 1-8) blended SI theory with constructs drawn from the Model of Human Occupation to explore self-actualization.

The Spiral Process of Self-Actualization

In Fisher and Murray's (1991) Spiral Process of Self-Actualization, SI theory is depicted in the medium gray spiral, and concepts drawn from the Model of Human Occupation are depicted in the white spiral. Inner drive, which provides the impetus to become involved in meaningful activities, is at the base of the spiral. Fisher and Murray defined "meaningful" as having significance, value, or purpose. For an activity to be meaningful, a child must be in control and able to make sense of the experience.

Actively taking in sensation *(sensory intake)* is an early step in the sensory integrative process. There are many sources of sensation, including the physical and social environments (represented by arrows labeled *environment*) and *production* and *outcome feedback.* Production feedback arises from the body and informs the child how it felt to move; outcome feedback arises from actions that produced a change in the environment.

Sensations are *integrated* (i.e., combined), enabling a child to act effectively and efficiently on objects in the environment. Ayres referred to these successful actions as *adaptive interactions.* Adaptive interactions give rise to production and outcome feedback. Adaptive (and sometimes not-so-adaptive) interactions are the behaviors we observe during evaluation.

Planning an adaptive interaction means knowing "what to do" and organizing "how to do it." Successful plans depend on a desire to participate, a sufficient body scheme developed from previous production feedback, and knowledge of outcome feedback from previous adaptive interactions. Production and outcome feedback are important to planning and ultimately to learning. After a neuronal model of an action is developed, it can be used as the basis for new, more complex interactions. Thus, Fisher and Murray added a third loop (dark lines) to their spirals to depict neuronal models (see Fig. 1-8).

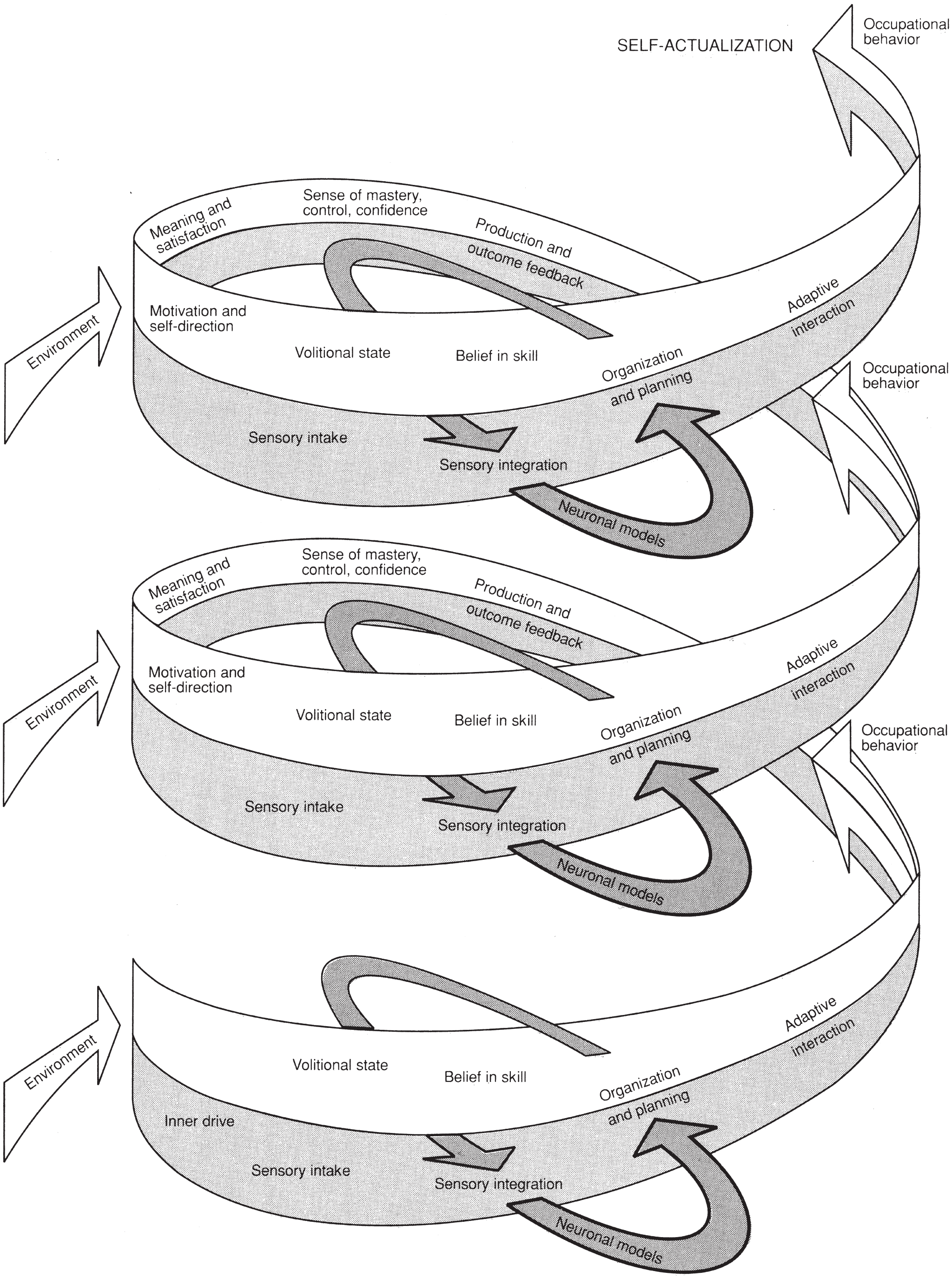


FIGURE 1-8 Spiral process of SI.

The white loop of the spiral reflects a core assumption of occupational therapy: Humans have an occupational nature. According to Fisher and Murray (1991), the addition of this loop to the traditional depiction of SI theory shows its place in the greater context of occupational science. Adaptive interactions are basic to occupational behavior. Two core assumptions of occupational science are that humans have an innate need to participate in occupation and that occupation is intrinsically motivating. In turn, humans develop meaning, satisfaction, confidence, self-control, and a sense of mastery from participation (White, 1959). Thus, the impetus for planning and organizing adaptive interactions includes both sensation and volitional factors (e.g., motivation, self-direction).

Adaptive interactions imply that individuals feel a certain amount of control over the task and the environment. Children who develop a *sense of mastery* also develop belief in their abilities (i.e., *belief in skill, self-efficacy*). Self-efficacy enables children to self-direct. They become motivated to explore their capacity through *planning and producing adaptive interactions* and participating in meaningful occupations.

In summary, through a spiral process of self-actualization, SI, beliefs about the self, and volition, together, contribute to adaptive interactions. In turn, adaptive interactions yield organized and effective occupational behaviors (e.g., self-care, play, academic performance). As children develop control over the environment and belief in their own skills, interactions with the environment become more meaningful and satisfying and children are likely to want to engage in similar actions and occupations repeatedly. Importantly, however, increased belief in skill does not necessarily or automatically accompany the ability to produce higher quality adaptive interactions. Therapists must ensure that children *know* that they have developed a new skill.

HERE'S THE POINT

- Blending psychosocial constructs with those inherent in SI theory, as is represented in the spiral model presented, provides a more complete picture of the child's strengths and needs, and lays a broader foundation for intervention.
- In the spiral process of self-actualization, SI, beliefs about the self, and volition are seen as contributing to adaptive environmental interactions. Adaptive interactions are the foundation for effective occupational behaviors.

All Theories Are Based on Underlying Assumptions

Accepting any theory means accepting the assumptions that underlie it. The assumptions underlying SI theory relate to its neural and behavioral bases. In Table 1-2, we describe four assumptions associated with sensory integrative therapy. We explain those assumptions and their rationale. We also list chapters in this text where readers can find more information.

Boundaries of Sensory Integration Theory and Intervention

Ayres envisioned the application of SI theory and intervention with particular populations: children with learning disabilities or autism. More recently, Parham and colleagues (Parham et al., 2011) defined specific criteria for sensory integrative therapy. Nonetheless, both practitioners and researchers sometimes apply SI theory in ways that are outside its boundaries. When therapists apply SI theory in other-than-intended ways, they must always proceed with particular caution. When researchers say they are investigating the **efficacy** of SI, they must ensure that their procedures are faithful to the principles of the theory. When they critique the theory, particularly through **meta-analysis** or systematic review, they must be certain that the papers they include actually reflect SI and not, as often seems to happen, prescribed techniques that include enhanced sensation but do not meet Parham et al.'s criteria. See also Chapter 14 (Distilling Sensory Integration Theory for Use: Making Sense of the Complexity) and Chapter 23 (Is Sensory Integration Effective? A Complicated Question to End the Book).

Boundaries and the Population

SI theory is intended to explain problems associated with dyspraxia or sensory modulation disorders. A diagnosis of sensory integrative dysfunction requires evidence of deficits in the central processing of vestibular, proprioceptive, or tactile sensation that are *not* attributable to frank peripheral nervous system or CNS damage or associated with cognitive deficits. Although Ayres (1972b) wrote initially about the difficulties of children with learning disorders, she (Ayres, 1979; Ayres & Tickle, 1980) later focused on children with autism. In the ensuing decades, we have learned unequivocally that many (or

TABLE 1-2 Four Assumptions Associated with Sensory Integrative Therapy

ASSUMPTION	EXPLANATION	RELATED CHAPTERS
The CNS has neuroplasticity.	Plasticity refers to the ability of brain structures to change. Ayres hypothesized that sensory integrative therapy could effect changes in the brain because of plasticity. Although Ayres emphasized the structural and behavioral plasticity of the young brain, there is ample evidence that plasticity is also present in the adult brain. Much of the support for plasticity and SI therapy is drawn from studies of the impact of enriched environments on the structure and function of the nervous system in animals (see, for example, Reynolds, Lane, & Richards, 2010).	18: Complementary Programs for Intervention; for review of literature on sensorimotor-based plasticity 21: Planning and Implementing Intervention: A Case Example of a Child with Autism
The brain functions as an integrated whole.	Ayres felt that SI occurred mainly in subcortical centers whereas cortical centers were responsible for abstraction, perception, reasoning, language, and learning. We now know that both cortical and subcortical structures contribute to SI.	4: Structure and Function of the Sensory Systems 5: Praxis and Dyspraxia
Adaptive interactions are critical to the development of SI.	The CNS is an open system, capable of self-regulating, self-organizing, and changing. Adaptive interactions *promote* SI, and the quality of a child's actions *reflects* SI. Active movements produce sensory feedback that forms the basis for neuronal models of "how it felt" to move. Knowledge of the outcome of an action forms the basis for memories of "what was achieved." Neuronal models, derived from production and outcome feedback, form the basis for planning increasingly complex adaptive interactions (Schmidt & Lee, 2011).	5: Praxis and Dyspraxia
Children have an inner drive to develop SI through participation in sensorimotor activities.	Ayres believed that all children have an inner drive to master their bodies and the environment. According to Ayres, inner drive is seen in excitement, confidence, and effort. She felt children with sensory integrative dysfunction sometimes seem to have little evidence of inner drive. Intervention leads to stronger evidence of the inner drive to seek out self-actualizing activities that, in turn, enhance SI (Ayres, 1972b). Fisher and Murray's Spiral Model of Self-Actualization, described previously, adds to this fundamental assumption.	12: The Art of Therapy; for in-depth depiction of capturing inner drive

most) children with autism process sensation abnormally (American Psychiatric Association, 2013). Several researchers (e.g., Baranek, Foster, & Berkson, 1997) as well as people diagnosed with autism (e.g., Grandin & Scariano, 1986) related poor processing of sensation to autism. Recent research utilizing rigorous designs including sophisticated case reports (Schaaf, Hunt, & Benevides, 2012), multiple baseline single case methodologies (Bulkeley, Bundy, Roberts, & Einfeld, 2016), and quasi-experimental or experimental designs (Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2013) have demonstrated decreases in problematic or stereotypic behaviors and increases in attainment of specific goals.

Sensory integrative dysfunction is a diagnosis of exclusion. That is, it is used to explain dysfunction in motor planning or sensory modulation that cannot be explained by frank CNS damage, genetic issues, or other diagnostic conditions. Children with a range of developmental disorders may have deficits in functions typically associated with sensory integrative dysfunction. However, SI theory is not intended to explain, for example, the depressed postrotary nystagmus, low muscle tone, poor proximal stability, or poor equilibrium experienced by children with Down syndrome or hearing loss. Their problems are more clearly attributed to abnormalities of the cerebellum (Nommensen & Maas, 1993) or damage to the eighth cranial nerve, respectively.

Boundaries and Intervention

The boundaries of SI theory also apply to intervention. Sensory integrative therapy involves taking in sensation actively in the context of meaningful, self-directed, adaptive interactions. The emphasis is on the integration of vestibular, proprioceptive, and tactile sensations and the promotion of posture, bilateral integration, praxis, or sensory modulation. Many direct intervention programs referred to as SI probably are more appropriately referred to as sensorimotor because, although they promote engagement in activities that involve sensory experiences, they are adult- rather than child-directed. Some involve only sensory stimulation because they involve passive application of sensation in a prescribed manner. Parham's and colleagues' (2011) criteria define sensory integrative therapy (i.e., ASI). (See also Chapter 12, The Art of Therapy, and Chapter 13, The Science of Intervention: Creating Direct Intervention from Theory.)

Boundaries and Critique

Not infrequently, critics apply the term *sensory integration* inappropriately to interventions that are purely sensory stimulation. Consider, for example, Lang et al. (2012), who published a systematic review entitled "Sensory Integration Therapy for Autism Spectrum Disorders." In reality, 9 of the 25 studies they reviewed evaluated the effectiveness of weighted vests, an example of passive application of tactile sensation (i.e., sensory stimulation), *not* of SI. Nonetheless, Lang et al. concluded, quite inappropriately given the papers included in their review, that there is insufficient evidence to support sensory integrative therapy for children with autism spectrum disorder (ASD). When reading or responding to such systematic reviews, we must consider carefully the nature of the individual papers included. Do they *actually* meet the criteria for SI? Neither publication in a credible peer-reviewed journal nor mention of Parham et al.'s fidelity measure in the introduction to their paper meant that the studies Lang et al. reviewed met the criteria for SI. When researchers such as Lang et al. conclude, based on studies that are *not* SI, that sensory integrative therapy is not effective, they simply fuel controversy inappropriately. (See also Chapter 15, Advances in Sensory Integration Research: Clinically Based Research, and Chapter 17, Using Sensory Integration Theory in Coaching.)

HERE'S THE POINT

- Understanding the boundaries of SI theory and intervention is essential.
- Constructs consistent with SI theory are useful in explaining the problems associated with dyspraxia and sensory modulation disorders. They are not intended to explain *all* developmental disorders.
- SI intervention elements have been captured in the fidelity measure developed by Parham and colleagues. They importantly include meaningful, self-directed, and adaptive interactions that are child directed and focused. Other sensory-based approaches may not include these central "ingredients."
- When considering intervention effectiveness studies, we must all remain vigilant that the intervention under scrutiny adheres to the essential features of ASI®.

Summary and Conclusions

In this chapter, we presented an overview of SI theory and sensory integrative dysfunction, comparing and contrasting two main categories of dysfunction: dyspraxia and sensory modulation dysfunction. We distinguished between two types of dyspraxia (i.e., deficits in bilateral integration and sequencing, somatodyspraxia) and two types of sensory modulation dysfunction (i.e., over-responsivity and under-) in terms of hypothesized sensory bases and overt indicators. We identified assumptions and boundaries of SI theory and SI intervention.

What makes occupational therapy practice different from all other health professions is our unique emphasis on "doing" occupation. The term *praxis,* derived from the Greek, also means doing, reminding us that, in employing SI theory, our primary concern is whether the children and adults with whom we work are able to *do* what they need and want to do.

Where Can I Find More?

Ayres, A. J. (1981; 2005). *Sensory integration and the child.* Torrance, CA: Western Psychological Services.

Lane, S. J., Smith Roley, S., & Champagne, T. (2013). Sensory integration and processing: Theory and applications to occupational performance. In B. Schell, G. Gillen, & M. Scafa (Eds.), *Willard & Spackman's occupational therapy* (12th ed., pp. 816–868). Philadelphia, PA: Lippincott, Williams, & Wilkins.

Parham, L. D., & Mailloux, Z. (2015). Sensory integration. In J. Case-Smith & J. C. O'Brien (Eds.), *Occupational therapy for children and adolescents* (7th ed., pp. 258–303). St. Louis, MO: Mosby.

Smith Roley, S., Schaaf, R. C., & Baltazar Mori, A. (2019). Ayres Sensory Integration® Frame of Reference. In P. Kramer, J. Hinojosa, & T.-H. Howe (Eds.), *Frames of Reference for Pediatric Occupational Therapy* (4th Edition, pp. 87–153). Philadelphia, PA: Wolters Kluwer.

Smith Roley, S., Blanche, E. I., & Schaaf, R. C. (2001). *Understanding the nature of sensory integration with diverse populations.* Philadelphia, PA: Harcourt Health Sciences Company.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Ayres, A. J. (1965). Patterns of perceptual-motor dysfunction in children: A factor analytic study. *Perceptual and Motor Skills, 20,* 335–368.

Ayres, A. J. (1966a). Interrelations among perceptual-motor abilities in a group of normal children. *American Journal of Occupational Therapy, 20,* 288–292.

Ayres, A. J. (1966b). Interrelationships among perceptual-motor functions in children. *American Journal of Occupational Therapy, 20,* 288–292.

Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities, 2,* 160–168.

Ayres, A. J. (1972a). Improving academic scores through sensory integration. *Journal of Learning Disabilities, 5,* 338–343.

Ayres, A. J. (1972b). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972c). *Southern California Sensory Integration Tests manual.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972d). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy, 26,* 13–18.

Ayres, A. J. (1975). *Southern California Postrotary Nystagmus Test manual.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1976). *The effect of sensory integrative therapy on learning disabled children: The final report of a research project*. Los Angeles, CA: University of Southern California.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy, 31,* 362–366.

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1985). *Developmental dyspraxia and adult-onset apraxia.* Torrance, CA: Sensory Integration International.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J., Mailloux, Z. K., & Wendler, C. L. W. (1987). Developmental dyspraxia: Is it a unitary function? *Occupational Therapy Journal of Research, 7,* 93–110.

Ayres, A. J., & Tickle, L. (1980). Hyper-responsivity to touch and vestibular stimulation as a predictor of responsivity to sensory integrative procedures in autistic children. *American Journal of Occupational Therapy, 34,* 375–381.

Baranek, G. T., Foster, L. G., & Berkson, G. (1997). Tactile defensiveness and stereotyped behaviors. *American Journal of Occupational Therapy, 51,* 91–95.

Brown, C., & Dunn, W. (2002). *Adolescent/Adult Sensory Profile.* San Antonio, TX: Pearson.

Bulkeley, K., Bundy, A., Roberts, J., & Einfeld, S. (2016). Family-centered management of sensory challenges of children with autism: A single-case experimental design. *American Journal of Occupational Therapy, 70,* 7005220040. doi:10.5014/ajot.2016.017822

DeGangi, G. A. (2000). *Pediatric disorders of regulation in affect and behavior: A therapist's guide to assessment and treatment.* San Diego, CA: Academic Press.

DiJoseph, L. M. (1982). Independence through activity: Mind, body, and environment interaction in therapy. *American Journal of Occupational Therapy, 36,* 740–744.

Dunn, W. (1994). Performance of typical children on the sensory profile. *American Journal of Occupational Therapy, 48,* 967–974.

Dunn, W. (2001). 2001 Eleanor Clarke Slagle Lecture—The sensations of everyday life: Empirical, theoretical, and pragmatic considerations. *American Journal of Occupational Therapy, 55,* 608–620.

Dunn, W. (2014). *Sensory profile 2: User's manual.* San Antonio, TX: Psychological Corporation.

Dunn, W., & Brown, C. (1997). Factor analysis on the Sensory Profile from a national sample of children without disabilities. *American Journal of Occupational Therapy, 51,* 490–495.

Dunn, W., & Westman, K. (1997). The Sensory Profile: The performance of a national sample of children without disabilities. *American Journal of Occupational Therapy, 51,* 25–34.

Fisher, A. G., & Murray, E. A. (1991). Introduction to sensory integration theory. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 3–29). Philadelphia, PA: F.A. Davis.

Grandin, T., & Scariano, M. M. (1986). *Emergence: Labeled autistic.* Novato, CA: Atena.

Henderson, S. E., & Sugden, D. A. (1992). *Movement assessment battery for children manual.* London, UK: Psychological Corporation.

Keogh, J., & Sugden, D. (1985). *Movement skill development.* New York, NY: MacMillan.

Kielhofner, G., & Fisher, A. G. (1991). Mind-brain body relationships. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 30–45). Philadelphia, PA: F.A. Davis.

Lai, J. S., Fisher, A. G., Magalhaes, L. C., & Bundy, A. C. (1996). Construct validity of the Sensory Integration and Praxis Tests. *Occupational Therapy Journal of Research, 16,* 75–97.

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders, 40*(1), 112–122. doi:10.1007/s10803-009-0840-2

Lane, S. J., Reynolds, S., & Dumenci, L. (2012). Sensory over-responsivity and anxiety in typically developing children and children with autism and attention deficit hyperactivity disorder: Cause or coexistence? *American Journal of Occupational Therapy, 66,* 1–9. doi:10.5014/ajot.2012.004523

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience, 4*(March), 8. doi:10.3389/fnint.2010.00008

Lang, R., O'Reilly, M., Healy, O., Rispoli, M., Lydon, H., Streusande, W., . . . Giesbers, S. (2012). Sensory integration therapy for autism spectrum disorders: A systematic review. *Research in Autism Spectrum Disorders, 6,* 1008–1018.

Mailloux, Z., Mulligan, S., Roley, S. S., Blanche, E., Cermak, S., Coleman, G. G., . . . Lane, C. J. (2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy, 65,* 143–151. doi:10.5014/ajot.2011.000752

May-Benson, T. (2001). A theoretical model of ideation. In E. Blanche, R. Schaaf, & S. Smith Roley (Eds.), *Understanding the nature of sensory integration with diverse populations* (pp. 163–182). Tucson, AZ: Therapy Skill Builders (now ProEd).

May-Benson, T. A. (2005). Examining ideational abilities in children with dyspraxia. Doctoral dissertation. Boston University. Ann Arbor, MI: ProQuest.

May-Benson, T. A., & Cermak, S. A. (2007). Development of an assessment for ideational praxis. *American Journal of Occupational Therapy, 61*(2), 148–153.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy, 61*(2), 135–142. doi:10.5014/ajot.61.2.135

Mulligan, S. (1996). An analysis of score patterns of children with attention disorders on the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy, 50*(8), 647–654.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy, 52,* 819–828.

Mulligan, S. (2000). Cluster analysis of scores of children on the Sensory Integration and Praxis Tests. *Occupational Therapy Journal of Research, 20,* 256–270.

Nommensen, A., & Maas, F. (1993). Sensory integration and Down's syndrome. *British Journal of Occupational Therapy, 56,* 451–454.

Parham, L. D., Ecker, C., Kuhaneck, H. M., Henry, D. A., & Glennon, T. J. (2010). *Sensory Processing Measure: Manual.* Los Angeles, CA: Western Psychological Services.

Parham, L. D., Roley, S. S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a fidelity measure for research on the effectiveness of the Ayres Sensory Integration® intervention. *American Journal of Occupational Therapy, 65,* 133–142.

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy, 65,* 76–85.

Reynolds, S., Bendixen, R. M., Lawrence, T., & Lane, S. J. (2011). A pilot study examining activity participation, sensory responsiveness, and competence in children with high functioning autism spectrum disorder. *Journal of Autism and Developmental Disorders, 41*(11), 1496–1506. doi:10.1007/s10803-010-1173-x

Reynolds, S., Lane, S. J., & Richards, L. (2010). Using animal models of enriched environments to inform research on sensory integration intervention for the rehabilitation of neurodevelopmental disorders. *Journal of Neurodevelopmental Disorders, 2*(3), 120–132.

Reynolds, S., Lane, S. J., & Thacker, L. (2011). Sensory processing, physiological stress, and sleep behaviors in children with and without autism spectrum disorders. *OTJR: Occupation, Participation, and Health, 32*(1), 246–257. doi:10.3928/15394492-20110513-02

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kelly, D. (2013).

An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders*, *44*, 1983–1988. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., Hunt, J., & Benevides, T. (2012). Occupational therapy using sensory integration to improve participation of a child with autism: A case report. *American Journal of Occupational Therapy, 66*(5), 547–555. doi:10.5014/ajot.2012.004473

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral approach* (5th ed.). Champaign, IL: Human Kinetics.

Sieg, K. W. (1988). A. Jean Ayres. In B. R. J. Miller, K. W. Sieg, F. M. Ludwig, S. D. Shortridge, & J. Van Deusen (Eds.), *Six perspectives on theory for practice of occupational therapy* (pp. 95–142). Rockville, MD: Aspen.

White, R. (1959). Motivation reconsidered: The concept of competence. *Psychological Review, 66,* 297–333.

CHAPTER

2

Sensory Integration in Everyday Life

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It's not some big event that creates the drama, it's the little things of everyday life that bring about that drama.

—Asghar Farhadi

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Explain how sensory integration (SI) fits into a view of development as multidimensional and transactional.
- ✔ Describe the relationship between sensory processing characteristics and participation in the everyday occupations of play and leisure; activities of daily living (ADLs) and instrumental activities of daily living (IADLs); rest and sleep; and education and work across the life span.
- ✔ Describe how assessment and intervention decisions are influenced by the complexity and transactional nature of development.

Purpose and Scope

The ultimate aim of occupational therapy practice using sensory integration (SI) principles is to help children meet the challenges that they encounter in their everyday lives at home, in school, and at play. These challenges can be as commonplace as realizing that one has been gently touched by a classmate or as unique as inventing a new game to play with friends on the playground.

Across the past five decades of research into SI, much work has focused on identifying patterns of sensory and movement difficulties and on documenting outcomes of interventions. Although the link between SI and what children do in everyday life has been evident since the early years of Ayres' work, it would be useful to cultivate a deeper understanding of the ways in which SI affects—and is affected by—participation in the daily activities that structure and give meaning to children's lives. A deeper understanding of these connections may lead to interventions that are more effective because they are more finely tailored to the life situations of individual children.

Ayres (2004) defined SI as the "organization of sensations for use" (p. 5). Those last two words, "for use," are revealing. Unlike neuroscientists, who often aim to isolate neural mechanisms, Ayres' central concern as an occupational therapist was with how the nervous system organizes sensory information so that the person can participate in meaningful and in productive occupations. SI-based intervention, therefore, became a tool for helping children engage in **occupations** that lead to rich and meaningful lives.

The primary purpose of this chapter is to help readers understand the important relationship between SI and everyday life—particularly the performance of everyday occupations, that is, the activities that people want or need to do. It also aims to raise questions that may guide future thinking about this relationship and how knowledge of this relationship might influence the design of programs and environments to benefit all people—not just those with clinically identified SI problems.

CASE STUDY ■ NICK

Nick is an 8-year-old boy assessed as having sensory integrative difficulties involving hazy **tactile discrimination** and immature **visual perceptual processing.** In addition, he has difficulty with the sequencing and timing aspects of **motor planning.** These praxis difficulties make it cumbersome for Nick to manage his body and objects in physical space and in synchrony with time constraints imposed by social expectations.

Nick is very aware of the general behavioral expectations placed on him by his teacher at school. However, his problems with SI and praxis make it difficult for him to comply with some of these expectations, even though he wants to do so. For example, he knows he is supposed to be able to reach into his desk and find his workbooks and tools (e.g., pencil, eraser, ruler) quickly, but his desk is chaotic, and he seems unable to keep it neat for longer than half a day. His tactile sense is not developed well enough to enable him to find and handle objects quickly and efficiently. He needs to rely on visual inspection to help him find things in his desk, but his visual system is not highly skilled either so this becomes an arduous task. His **somatodyspraxia** further interferes with his adeptness in handling classroom materials and tools. His classmates, whose sensory integrative and praxis abilities are well developed, are able to find and manage their materials quickly and easily, even those who do not have stellar desk organization habits.

Closer observation of Nick may reveal that he actually does not seem aware of some of the finer nuances of his teacher's expectations for her students. Whereas other students figure out that her expectations require that they work out strategies for desk management, Nick does not realize that he needs to do this. This may be caused at least partially by his sensory and praxis difficulties, which have limited his experiences and his success in developing effective and sophisticated strategies for the organization and manipulation of objects. In Nick's eyes, other kids just magically know how to reach into their desks and instantly find their school materials. His lack of recognition of the need for organizational strategies to manage his body and physical objects in space and time extends beyond desk management into other realms, such as playground games and sports with peers. Thus, he does not realize the full ramifications of many social expectations, such as the expectations for team members during a soccer game.

Nick's experiences as he engages in a variety of daily routines—his successes and failures, pleasures and pains—will influence his future preferences and choices of occupations. He has strong verbal skills and already shows a definite preference for occupations such as reading and telling jokes. He also has an avoidance of sports and games that require skill in sequencing of actions or precision in object manipulation. Of course, not all of his choices will be related to his verbal talents or his sensory integrative difficulties; many will be derived from personal experiences with significant people, places, things, and events. For example, the flowers that brighten his loving grandmother's backyard give him feelings of joy, security, and contentment. The pleasant memories of his grandmother's garden, as well as the sensory experiences that he enjoys while gardening, eventually may lead him to value the occupation of gardening. Yet, it is possible that his sensory integrative characteristics will have a lifelong influence on his choices of leisure and work occupations. In an optimal scenario, he may become a successful attorney if he has supportive family and friends, if he continues to hone his verbal talents, and if he learns to exercise good judgment in deciding when to use verbal strategies to organize tasks and when to delegate. He may experience a great deal of satisfaction and enjoyment while gardening at home. However, it is very unlikely that he will become a professional athlete, and he probably will not choose to participate regularly in a team sport as a leisure activity.

Clearly SI is a factor in the formation of Nick's identity, although it most certainly is not the only factor, and it may not even be the most important factor. The formation of his identity is shaped by—and shapes—the occupations in which he engages. Through time, Nick's appraisal of who he is becoming in relation to what he values most in life will affect his overall satisfaction with his life circumstances. The presence of sensory integrative difficulties definitely does not mean that a person is doomed to be unsuccessful or unhappy. But it may present special challenges. Repeated experiences of failure may cumulatively lead to feelings of hopelessness and incompetence, avoidance and fear of challenge, a constricted range of meaningful occupations, and poor life satisfaction. Conversely, if a person's experiences lead to a strong sense of self-efficacy, the challenges posed by sensory integrative difficulties actually may contribute to the forging of self-discipline, determination, hope, character, and, consequently, a rich occupational life with a high degree of life satisfaction.

The Complexity of Everyday Life

Occupational therapists have long recognized that engagement in everyday activities is not as simple as meets the eye. Getting dressed, for example, requires the activation and coordination of physical body structures by processes that involve genomic, physiological, cognitive, and affective events, all working in synchrony. Moreover, the specific actions and experiences that occur while getting dressed are shaped by the constraints and opportunities presented by the physical environment—materials, objects, surfaces, and ambient surroundings—as well as the person's interpretation of the place where the actions occur and the sociocultural expectations that permeate the situation. Even spiritual aspects of experience (i.e., the experience of life meaning and purpose) may be evoked during commonplace activities, such as dressing. For example, when difficulties arise during the performance of ordinary activities, the person may not only become dissatisfied and frustrated but also may question the worth of his or her own life. (See also Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited.)

The complexity and multiplicity of factors that shape lives make it impossible to predict with any precision what the specific life outcomes will be for a particular child who has sensory integrative problems. The developmental process is extremely complex because, not only are multiple factors simultaneously involved, but also it is transactional in nature. That is, biologically based predispositions and environmental influences mutually affect each other through dynamic interchanges, so developmental outcomes are the result of a confluence of multiple factors that change through time as they influence each other (Sameroff, 2009). This means that not only is it impossible to predict long-term life outcomes for an individual child, but also it is usually inappropriate to look back across the life of a person who has significant life problems in search of a single, specific cause of those problems.

As an example, consider an infant who is over-responsive to tactile, vestibular, and auditory stimuli and has a young, impulsive mother who is very stressed by her low-income living situation and the very limited support she receives from family or friends. The baby recoils when touched by his mother, and if environmental sounds become intense (as they often do in the small apartment with thin walls), he screams inconsolably. The infant's defensive behaviors heighten the stress of the mother, who begins to dread interacting with her infant. She perceives him as a problem baby who does not like her so she tries to complete infant caregiving activities (e.g., feeding, diapering, and bathing) as quickly as possible in order to be freed to leave him alone in the bedroom to cry and eventually fall asleep. Her insensitive handling of him aggravates his sensory defensiveness, and consequently he cries increasingly more often and more intensely. In a worst-case scenario, the mother may try to cope with this escalating situation by physically and emotionally neglecting or even abusing her baby.

Four years go by, and we see the baby grow into a preschooler who struggles to engage in play for more than a fleeting time. Not only does he have trouble with solitary play but also he seems unable to play with peers without acting out aggressively and destructively. In the preschool setting, he stands out as a child who is having great difficulty.

In this example, what was the original cause of the child's preschool difficulties? His sensory defensiveness or his mother's stress? The mother's impulsive personality or the baby's difficult temperament? Is the cause the mother's lack of access to resources and supports or her lack of knowledge regarding how to engage with the child sensitively during daily routines? All are legitimate causes because each of these issues affects the others, and all of them interact synergistically to shape the child's life. It would be inappropriate to single out one as the sole cause, although some may exert more powerful effects than others.

Even in such an extreme example as this one, the very rocky beginning in the mother-infant relationship will not necessarily doom this infant to future failure. (See also Chapter 19, Application of Sensory Integration with Specific Populations.) All along the life course, events and experiences arise that shape and guide who the child is becoming. We can imagine a different preschool outcome for the difficult infant in our previous example if, for example, we introduce a day-care provider into the picture when the baby is a toddler. Let us imagine that this day-care provider is gifted at intuiting the toddler's needs and fine-tunes the day-care environment so that he is not overwhelmed by sensations, he experiences pleasure and mastery in simple sensory-motor activities, and he is cared for by an adult who is nurturing but also sets limits on his behavior in a consistent manner. Furthermore, the day-care provider forms a positive relationship with the infant's mother and mentors her in mothering. It is likely that the child's later preschool experiences will not be as negative in this scenario compared with what the situation might have been had he not had the good fortune of an optimal day-care experience.

SI is one of the factors that shapes life outcomes. However, it is only one of many potentially powerful factors. It is probably never appropriate to identify poor SI as the sole cause of a child's problems in everyday life or to claim that a child will have specific problems in the future because of the presence of sensory integrative difficulties. But SI does contribute to what, how, and why a person engages in particular activities at particular times in the life cycle. For Nick, who was introduced earlier in this chapter, SI may be a key contributor to his difficulties when trying to play sports or manage items in and around his desk. However, the reactions of peers and teachers to his disorganization on the sports field and in the classroom may be just as powerful, perhaps even more so. For example, peer ridicule or rejection on the sports field may instill embarrassment and shame, leading him to avoid these activities. Avoidance, in turn, results in fewer opportunities to acquire and master the motor skills required in these activities, so the gap in motor skills between Nick and his peers widens through time.

So, the answer to the question, "Does poor sensory integration cause problems in everyday living?" is "Probably, but it does not determine outcomes by itself." Poor SI does not single-handedly cause difficulties with daily activities. It interacts with talents, physical attributes, environmental opportunities, contexts, past experiences, social expectations and responses, and a host of other factors, all changing through time and affecting one another, to shape and color the person's occupational life. (See also the Spiral Process of Self-Actualization described in Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited.)

Given the complexity of multiple influences on developmental outcomes, how can we be sure that SI is a significant factor in daily life, deserving of attention? Is SI critical enough that we should pay attention to it when conducting assessments and planning interventions for children with developmental, learning, or social difficulties? The following section examines research that addresses this issue.

HERE'S THE POINT

- Everyday life activities involve ongoing transactions between complex aspects of the person—including SI characteristics—and complex aspects of the activity context.
- SI is one of many factors that shape our relationships with others and what we are able to do across the life span.

Sensory Integration and Everyday Life: The Evidence

Research exploring the relationship between SI and **participation** in everyday life activities is growing. During the past 10 years, it has become increasingly clear that SI differences can affect individuals in all areas of life, starting at birth and continuing throughout the life span. A systematic review of 35 studies on children with SI difficulties indicated that sensory problems were related to occupational performance difficulties in all areas of everyday life: play, activities of daily living, sleep, and work, including school performance (Koenig & Rudney, 2010). Taken together, these studies provide evidence that sensory integrative characteristics are a potentially critical factor in shaping lives, particularly with respect to people's engagement in occupations. For example, sensory integrative differences may affect how people use their time, relate to others, and interact with their physical and social worlds across the life span.

In this section of the chapter, we will briefly examine the relationship between engagement in occupations across the life span in four major life areas: (1) play, leisure, and social participation; (2) activities of daily living and instrumental activities of daily living; (3) rest and sleep; and (4) education and work. Although the majority of the research presented here addresses the difficulties and limitations associated with SI differences, it is important to recognize that it is possible for there to be some benefit to these differences as well. When planning intervention, the challenge is identifying the combination of environments, relationships, and activities that best supports an individual's participation.

Several specific diagnostic groups have been found to have high rates of SI differences, such as individuals with autism spectrum disorder (ASD) (Bagby, Dickie, & Baranek, 2012; Baranek, David, Poe, Stone, & Watson, 2006; Hilton, Graver, & LaVesser, 2007; Hochhauser & Engel-Yeger, 2010; Lane, Young, Baker, & Angley, 2010; Leekam, Nieto, Libby, Wing, & Gould, 2007; Miller Kuhaneck & Britner, 2013; Reynolds, Bendixen, Lawrence, & Lane, 2011); some genetic conditions, such as Fragile X syndrome (FXS) (Baranek et al., 2002); and developmental coordination disorder (DCD) (Smyth & Anderson, 2000). However, each of these diagnoses, by definition, involves difficulties in areas of functioning, such as communication skills, motor skills, or intellectual ability, any of which can interfere with participation in everyday activities. The confounding of SI problems with developmental and medical diagnostic conditions makes it difficult to ascertain whether SI differences play a significant role in child participation beyond the impact of concomitant diagnostic conditions.

Few researchers have attempted to extricate the impact of SI factors from other factors on functional performance. An exception is research conducted by Reynolds and colleagues on children with ASD (Reynolds, Bendixen, et al., 2011). Their multivariate analyses of data for 52 children (26 with ASD and 26 with typical development) showed that high levels of sensory over-responsiveness (i.e., sensory sensitivity and sensory avoidance) were significantly associated with lower levels of competence in activity, social, and academic participation, suggesting that sensory difficulties adversely affect participation regardless of diagnosis. Furthermore, in these analyses, cognition (as measured by nonverbal IQ) did not significantly contribute to any aspect of participation.

In the remainder of this discussion of evidence regarding SI and participation, we will focus primarily on individuals who are not identified as having a particular diagnostic condition, although, where appropriate, we refer to similar findings in children who have diagnosed conditions often characterized by difficulty processing sensation (e.g., FXS, ASD, DCD). As you will see, even individuals who are otherwise typically developing can experience significant participation difficulties that are related to their SI abilities. For individuals with diagnosable conditions involving motor skills or communication, the SI difficulties are likely to be even greater. Therefore, by focusing the discussion on individuals without concomitant developmental or medical conditions, this chapter aims to present a conservative picture of the impact of SI differences on everyday life. The reader should keep in mind that the impact of SI problems is likely to be compounded by other diagnosable conditions, when these are present. Conversely, in some situations and tasks, having a sensory difference may provide an advantage.

Play, Leisure, and Social Participation

Currently, most of the research that addresses the impact of SI characteristics on everyday life is focused on play, leisure, and social participation. The existing evidence indicates that, even for individuals without an identified medical diagnosis or disability, sensory integrative characteristics may impact significantly on participation in play and leisure activities (Watts, Stagnitti, & Brown, 2014).

The impacts of sensory integrative differences can be seen in young infants. An infant's ability to process and integrate sensory information

FIGURE 2-1 Sensory integrative abilities in both the mother and child are important for bonding as well as the development of the infant's social and self-regulatory abilities.

effectively can have a clear impact on mother-infant **coregulation,** which, in turn, directly affects infant engagement in **co-occupations** (Esdaile & Olson, 2003; Pierce, 2009; Zemke & Clark, 1996), such as simple reciprocal social interactions and play with the caregiver (e.g., reciprocal vocalizations and games, such as peekaboo) (Fig. 2-1). Researchers have found that infants with SI differences may be fussier and have more difficulty forming typical attachments than infants with developmentally appropriate SI (DeSantis, Coster, Bigsby, & Lester, 2004; Hofer, 2006; Purvis, McKenzie, Cross, & Razuri, 2013). These challenges affect the quality of engagement as well as the amount of time that infants can sustain engagement in play and social participation and can be magnified when the mother as well as the infant has difficulties integrating sensory information effectively (Turner, Cohn, & Koomar, 2012)—a reflection of the transactional nature of the developmental process.

Researchers have found that early difficulties connecting with and relating to other people can persist throughout childhood. In early childhood, SI differences appear to be related to play in children with ASD. Specifically, a child's praxis skills and abilities to process visual, touch, proprioceptive, and vestibular information are associated with social play (e.g., sharing or playing cooperatively) (Miller Kuhaneck & Britner, 2013). Additionally, sensory integrative characteristics are related to the types of toys children select for play in early childhood. A study of typically developing 3- to 5-year-olds showed that children who demonstrate a preference for toys that promote fantasy play (e.g., dollhouses, toy dinosaurs) had a tendency to exhibit more sensation-seeking behaviors than peers who preferred creative art and building materials (Mische Lawson & Dunn, 2008). Further evidence indicates that sensory over-responsiveness of parents is significantly associated with over-responsiveness in their otherwise typically developing children and that parent tendency to not engage in sensory-seeking activities may limit child exposure to sensory-stimulating activities (Welters-Davis & Mische Lawson, 2011). These findings, again, suggest that SI may play an important role in the transactional processes of child development.

The impact of SI on activity choices and play continues through middle childhood. Many children with sensory integrative difficulties may be able to compensate well for their sensory differences by harnessing strengths to develop typical play skills (Bundy, 1989; Clifford & Bundy, 1989). However, recent studies indicate that sensory differences often interfere with play participation (Fig. 2-2). Bundy, Shia, Qi, and Miller (2007) found that sensory modulation dysfunction has a negative impact on the playfulness of children. A case study presented by Benson, Nicka, and Stern (2006) illustrates how this may be manifested. They described the play characteristics of a 6-year-old boy with sensory integrative dysfunction who demonstrated limited and cautious play, poor attention to play activities, and minimal emotional investment in his play.

In middle childhood, SI difficulties may lead to limited play preferences and restricted social networks with peers. Cosbey, Johnston, Dunn, and Bauman (2012) found that children with SI differences engaged in more solitary play than their peers and did not show the same shift to organized games-with-rules play as their peers. Similar findings have been discovered for children with DCD (Smyth & Anderson, 2000). Additionally, through structured interviews of children with and without SI differences, Cosbey, Johnston, and Dunn (2010) found that children with SI differences tended to demonstrate more limited social networks, and spent less time

FIGURE 2-2 Children with sensory-based dyspraxia may have difficulty learning new motor skills and get left out of social activities and experiences typically engaged in by their peers.

with friends, than peers without SI difficulties. Although the children's activity preferences were similar across the two groups, children with SI differences indicated the least enjoyment for activities with formal rules and clear expectations. Interestingly, three of the most preferred activities for children with SI differences (quiet tabletop activities, pretend play, and computer or video games) were the three areas that were the least preferred by their peers. Hochhauser and Engel-Yeger (2010) reported similar findings for children with ASD, indicating that the children with ASD had limited ranges of activities and tended to have a smaller social network than their typically developing peers.

Other researchers examining the play, leisure, and social participation of children with ASD have found that there is a link between social competence and sensory processing abilities, with the presence of more sensory difficulties related to poorer social competence (Hilton et al., 2007; Reynolds, Bendixen, et al., 2011). Further, sensory integrative abilities impact family activity choices of families of children with and without ASD (Bagby et al., 2012). Collectively, this body of research suggests that a school-aged child's play, leisure, and social participation may be impacted by SI differences. The impact seems to be even more pronounced when the sensory integrative differences are concomitant with other conditions, such as ASD.

Limited research examines the relationship between SI and everyday life for adolescents. Existing studies indicate that risk-taking and sensation-seeking behaviors are characteristic of typical adolescents (e.g., Lightfoot, 1997; Zuckerman, 1994). Zuckerman (1994) defined *sensation seeking* as "the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience" (p. 27). Some evidence (e.g., Greene, Krcmar, Walters, Rubin, & Hale, 2000) suggests that adolescents who engage in more sensation-seeking behaviors (as defined by Zuckerman) are more likely to engage in delinquent behaviors. These teens seem to have intense responses to novel stimuli and seek out activities and opportunities to experience these stimuli. However, other researchers (Shea & Wu, 2012) have found that adolescents who are involved with the juvenile justice system tend to show fewer sensation-seeking behaviors and more sensation-avoiding behaviors than other teens.

These two sets of findings appear to contradict each other, but this may be because of the use of different theoretical models by the researchers. The term *sensation seeking* connotes different meanings depending on the theoretical framework being used. In contrast with the Zuckerman conceptualization, Shea and Wu (2012) used this term in a manner that is consistent with Dunn's conceptualization of sensory seeking as a manifestation of high neurological threshold for responses to sensory stimulation (i.e., requiring intense sensory input in order to respond to stimuli) and in combination with a tendency to actively seek out input to reach that threshold (Dunn, 1997). Shea and Wu (2012) also used Dunn's conceptualization of sensation avoiding (i.e., active avoidance of sensations in conjunction with a low neurological threshold for responses to sensory stimulation). Regardless

HERE'S THE EVIDENCE

Reynolds, S., Bendixen, R. M., Lawrence, T., & Lane, S. J. (2011). A pilot study examining activity participation, sensory responsiveness, and competence in children with high functioning autism spectrum disorder. *Journal of Autism and Developmental Disorders, 41,* 1496–1506.

This descriptive cross-sectional study compared activity participation and perceived competence in two groups of children with (n = 27) and without (n = 28) ASD from 6 to 12 years of age. The Child Behavior Checklist (CBCL) competence scales were completed by parents who answered questions related to their child's participation in the areas of activities, social life, and school performance. The Sensory Profile also was completed by parents as a means of comparing children's sensory processing abilities to their competence in performing and participating in daily life tasks. When the researchers examined the types of leisure activities participated in by each group, the children with ASD had more involvement in video games, playing with transportation vehicles, and reading books; they had less involvement in dramatic play, play with dolls or action figures, or in arts and crafts activities. Overall, parents of kids who were developing typically were able to identify more leisure activities participated in by their children than parents of kids with ASD. Children with ASD were also found to participate in fewer jobs or chores at home, with 27% of children with ASD having no chores at home compared with only 7.6% of kids developing typically who had fewer than two chores. Overall, children with ASD had less involvement in chores related to animal care, babysitting, or general cleaning around the home. When the researchers compared competence scores between the two groups, the group with ASD was found to have significantly lower levels of competence in each area (p = .000 across all three domains: activity participation, school performance, and social participation). Subsequent analyses identified that sensory over-responsive scores on the Sensory Profile (elevated behaviors of sensation avoiding and sensory sensitivity) were significantly correlated with lower levels of competence. The authors suggest in their discussion that children who show sensory over-responsiveness may be less likely to engage in activities that require the processing of self-perceived noxious sensory inputs and that they may not perform tasks successfully when they do attempt to engage. This study suggests a role for occupational therapists in helping children with sensory modulation disorders find and be successful in meaningful play and leisure activities as well as helping parents to determine which jobs or chores the child can take on within the household to ensure he or she experiences the same types of learning and maturational opportunities as other children.

of whether the Zuckerman or Dunn conceptualization of "sensation seeking" was used, the researchers found that adolescents who have intense reactions to sensory input (either actively seeking or actively avoiding) are more likely to engage in delinquent behaviors. What is not clear from the current research is how active sensory-seeking and avoiding behaviors may be related to delinquent behavior.

Other researchers have found that teens who have been involved negatively with law enforcement tend to have SI difficulties as demonstrated by their performance on vestibular- and praxis-related tests (Fanchiang, Snyder, Zobel-Lachiusa, Loeffler, & Thompson, 1990). In another study, sensory integrative differences were found to be related to non-suicidal self-injurious behaviors (e.g., self-cutting) in young adolescents (Christensen, 2012). Teens engaging in these behaviors demonstrated greater sensitivity to sounds as well as tendencies toward sensation avoiding and low registration. Although this body of research does not directly address conventionally accepted modes of play, leisure, and social participation, it provides some insight into some behaviors in which teens with SI differences may engage outside of time designated for school, work, self-care, and sleep.

SI differences may indirectly affect engagement in play, leisure, and social participation in adulthood through its impact on emotional states and social relationships. SI differences are strongly associated with anxiety (Engel-Yeger & Dunn, 2011b; Green & Ben-Sasson, 2010; Kinnealey, Koenig, & Smith, 2011; Reynolds & Lane, 2009), and a growing body of evidence on adults suggests a relationship between SI and affect (Engel-Yeger & Dunn, 2011a); relationship styles and ability to cope (Jerome & Liss, 2005); and **temperament,** including expression of anger (Stols, van Heerden, van Jaarsveld, & Nel, 2013), social introversion, depression, and impulse control (Kimball, Birstler, Bosse, Nelson, & Woods, 2012). Further, research (Kinnealey et al., 2011) suggests that adults with SI differences may have more limited social supports and lower perceived health-related quality of life, including social functioning. Finally, quantitative research as well as first-person accounts of living with SI differences (Kinnealey, Oliver, & Wilbarger, 1995; McCarter, 2010) suggest that sensory integrative differences may impact adults' interpersonal relationships via physical intimacy and activity choices.

This rapidly growing research base provides evidence that SI differences are related to occupations (e.g., play, leisure) and performance, especially social interaction, skills. Throughout the life span, SI has the potential to influence our occupation and activity choices, from the types of toys a toddler plays with to the leisure activities of adolescents and engagement in social activities by adults. Additionally, SI differences are connected to difficulties in fundamental social-interaction skills that affect engagement in play and social participation, from fussiness in an infant to anger and anxiety in an adult. However, because of the transactional nature of the developmental process, negative outcomes for individuals with sensory integrative differences are not inevitable. Supportive contexts and environments that permit an individual to capitalize on strengths and talents (i.e., client factors) while building new performance skills may lead to a highly successful and satisfying life.

Activities of Daily Living and Instrumental Activities of Daily Living

Engagement in **activities of daily living (ADLs),** such as dressing, eating, and bathing, as well as **instrumental activities of daily living (IADLs),** such as shopping, preparing food, and housekeeping, are essential and often time-consuming aspects of everyday life. As with play, leisure, and social interaction skills, evidence shows that SI differences impact performance of ADLs and IADLs beginning in infancy. Infants with SI differences tend to be fussier and have more difficulty establishing appropriate attachment to caregivers (e.g., DeSantis et al., 2004; Hofer, 2006; Purvis et al., 2013), which can affect an infant's ability to participate in co-occupations with caregivers, such as dressing, bathing, and eating. Sensory defensiveness may have a negative effect on breastfeeding (Radzyminski, 2005; Weiss-Salinas & Williams, 2001).

Eating difficulties appear to persist through childhood and adolescence. One of the most widely documented ADL areas impacted by SI differences is the area of feeding and mealtimes. Children with sensory integrative differences tend to have inordinate difficulty accepting new foods (Blissett & Fogel, 2013), and many children referred to feeding clinics tend to have sensory integrative differences (Davis et al., 2013). They also may have difficulty participating in family routines related to meal preparation because of the sensory characteristics of those routines, such as loud appliances and the tactile and olfactory aspects of cooking (Bagby et al., 2012). Sensory integrative difficulties also have been implicated in other areas of children's ADLs, such as toileting and dressing (Bellefeuille, Schaaf, & Polo, 2013; O'Neil, 2010; Schaaf, 2011). Reynolds and Lane (2008) presented case reports of children with tactile sensitivity, illustrating that ADLs, including difficulties with hair washing and combing, nail clipping, toothbrushing, dressing, and eating, can be difficult for them. These difficulties may be compounded by other conditions. For example, Baranek and colleagues (2002) reported that boys with FXS who had increased aversive and avoidance reactions to sensory stimulation were also more likely to be less independent with their ADLs.

Sensory integrative difficulties are related to ADL and IADL performance by adults. In a qualitative study, Kinnealey, Oliver, and Wilbarger (1995) documented that adults with sensory integrative differences reported restrictions in clothing and food choices, difficulty with meal preparation activities, and difficulty with visits to the dentist. The adults in this study also reported that their sensory integrative differences impacted other aspects of self-care, such as choice of jewelry and whether or not they wore make-up. Pohl, Dunn, and Brown (2003) found that adults tend to demonstrate lower levels of registration of sensory input as they age, which has potential negative implications for their ability to drive, navigate within their community, and complete self-care activities appropriately.

This research indicates that sensory integrative differences have a lifelong impact on an individual's participation in ADLs and IADLs.

Feeding, the earliest and most pervasive ADL, appears to be related to sensory integrative abilities from birth through adulthood and may affect nutritional intake as well as ability to participate in meals shared with others. As the performance demands increase, individuals with sensory integrative difficulties are increasingly likely to encounter ADLs and IADLs that are stressful. The presence of sensory difficulties, therefore, may restrict engagement in a wide range of activities and, ultimately, may limit the person's access to community places and events.

Rest and Sleep

Little research has examined the relationship between SI differences and the vitally important occupations of rest and sleep, but the existing evidence is consistent in finding a significant association between sensory differences and sleep difficulties. Researchers (Wiener, Long, DeGangi, & Battaile, 1996) have found that full-term infants who demonstrated SI differences at 7 to 18 months of age were likely to have difficulties with sleep (Fig. 2-3). Other researchers have documented a link between sensory hypersensitivity and disrupted sleep among children without disabilities (Shochat, Tzischinsky, & Engel-Yeger, 2009) as well as adults (Engel-Yeger & Shochat, 2012). At least one study (Reynolds, Lane, & Thacker, 2011) has documented that children with ASD have a high prevalence of atypical sensory behaviors that are associated with sleep disturbance. Furthermore, in this study, behavioral and physiological (i.e., body function) measures of sensory responsivity distinguished between good and poor sleepers with 85% accuracy, suggesting that sensory difficulties are important factors in understanding and planning intervention for the many children with ASD who have sleep deficits. Further research is necessary to fully describe the relationship between rest and sleep and SI patterns, but this preliminary research suggests that there is a potentially powerful link that should be explored more completely.

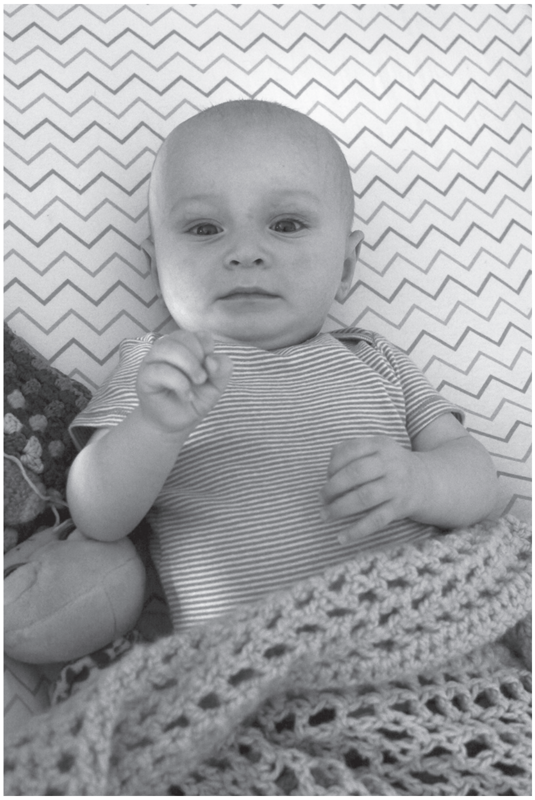

FIGURE 2-3 Sensory sensitivities may make it more difficult for children to fall asleep and stay asleep.

Education and Work

Although little research has specifically assessed the relationship between SI and education or work performance, many researchers have theorized about the potential relationship. For example, Geva and Feldman (2008) presented a conceptual framework of infant development that places the ability to regulate and integrate sensory information as a key element of development. According to their model, secondary skills of emotion and attention regulation, which ultimately lead to higher level learning skills (e.g., cognitive processing and self-regulation), are dependent on SI. There are several other models that also identify SI as an essential foundational element of learning experiences, which could include participation in education and work activities (Dunn, 1997; Trott, Laurel, & Windeck, 1993; Williams & Shellenberger, 1996).

The relationship between SI and education has been explored in school-aged children and adolescents. SI differences have been found to be related to academic achievement in both reading and math (Parham, 1998). Specifically, sensory integrative differences in children who were 6 to 8 years old were found to predict arithmetic achievement 4 years later, after statistically controlling for intellectual ability and family socioeconomic level. This relationship was strong, particularly with regard to praxis skills. A different relationship was found between SI and reading achievement, with SI demonstrating a predictive relationship at the older (but not younger) ages (Parham, 1998). A similar finding was reported for children with FXS (Baranek et al., 2002), with lower scores in school functioning linked to greater SI differences. Difficulties with participation in typical school activities, including navigating the school environment, recess, assemblies, lunch, handwriting, and participating in other classroom activities, also have been reported (Bagby et al., 2012; McCarter, 2010; Reynolds & Lane, 2008; Smyth & Anderson, 2000).

Although the relationship between SI and education or work has not been thoroughly explored during adulthood, our understanding of SI and the critical role it plays in supporting participation in life activities suggests that it is likely that a relationship exists (Fig. 2-4). Some first-person narratives and case reports support this hypothesis. For example, Fanchiang (1996) presented a case report of a young man with a learning disability and SI differences. Fanchiang theorized that the young man's career choices may have been influenced by his SI characteristics, with the role of massage therapist fulfilling his own needs for intense sensory input. Temple Grandin, a well-known adult with ASD, has written about the relationship between vocational choices and sensory integrative as well as cognitive characteristics and interests (Grandin, 2006), and her own highly successful career in designing equipment for the cattle industry clearly capitalizes on her visual strengths. Therefore, it appears that SI characteristics influence career choices and that building on strengths while acknowledging sensory-based challenges may lead to a more successful and satisfying work life.

FIGURE 2-4 An individual with sensory overresponsivity may choose to pursue work activities that require limited social interaction and occur in a controlled, low stimulation environment.

HERE'S THE POINT

- Research evidence indicates that SI characteristics influence a person's participation in various occupations—play and leisure, ADLs, sleep and rest, and work and education—across the life span.
- Limitations in participation, attributable to differences in sensory integrative processing, may be seen in diagnostic populations typically seen by occupational therapists, including adults and children with ASD, DCD, FXS, and sensory integrative disorders.

Implications for Assessment and Intervention

In this chapter, we have focused on how SI influences participation in everyday occupations. So far, we have discussed the transactional process of development, which influences how SI interacts with other factors to affect participation, and we have summarized the research evidence surrounding the influence of SI on engagement in everyday occupations. Now we will consider a few of the implications that these ideas have for clinical practice.

Assessment: Looking to the Future, Considering the Past

Because occupational therapy is a practice profession that is centrally concerned with occupation as a key aspect of health and well-being, therapists should place occupation at the front and center of the assessment process. But because occupation is complex and affected by multiple ongoing transactions between person and context, the assessment process must be flexible and responsive to the unique situation of each child and family.

Periodically, leaders in different areas of occupational therapy practice (e.g., Brown, 2012) have recommended that therapists avoid a bottom-up assessment approach, instead embracing a top-down approach. By "bottom-up," we mean that assessment begins with a focus on specific components believed to be affected by the child's condition, such as strength, coordination, or perceptual skills (Trombly, 1993). In the field of SI, an example of a bottom-up assessment strategy might be administration of the Sensory Integration and Praxis Test (SIPT) (Ayres, 1989) as a first step in assessment of a child with a diagnosis of attention deficit disorder. If this is the initial approach to assessment, we might consider it to be component driven (Gray, 1998) because concerns with sensory, perceptual, and motor components are driving the assessment and subsequent intervention.

In contrast, "top-down" refers to an assessment process that begins with information-gathering related to occupation; in other words, what the person wants and needs to do, the contexts for performing these occupations, and the current strengths and limitations in performing the desired occupations (Brown, 2012; Coster, 1998; Fisher, 1998; Fisher & Marterella, 2019; Fisher & Short-DeGraff, 1993). For example, an occupational therapist who uses a top-down strategy with a child diagnosed with attention deficit disorder initially will gather information regarding what the child wants and needs to do (according to the child, the parents, and other important people in the child's life, such as teachers), what the contexts are for the child's current occupations (e.g., school, home, community settings), and what the child and others perceive as the current successes and problems the child experiences in doing valued occupations. This initial investigation then will lead to decisions regarding whether further assessment of specific skills or abilities is warranted, including administration of the SIPT.

Use of a top-down strategy, therefore, puts the assessment of sensory integrative functioning into the broader context of the child's life. This contextualizing of SI assessment is potentially more likely to be perceived by families as helpful and relevant, compared with assessment procedures that seem remote from everyday life.

A problem with the top-down assessment approach is that it focuses on problems in occupation only at the time of assessment (Coster, 1998; Fisher, 1998). However, occupational therapists project into the future as they plan the course of therapy with their patients. In fact, in their qualitative study of occupational therapists engaged in practice, Mattingly and Fleming (1994) claimed that occupational therapists imagine who their patients will become in the future and, further, that they create stories with the patient about what has happened in the past and what will happen in the future as the person's life unfolds. Perhaps occupational therapists should include in their clinical assessments the hopes and wishes of the family for the future, especially with regard to the occupations that the child will want and need to do in a few years (for example, see Cohn, Kramer, Schub, & May-Benson, 2014).

The transactional view of development also suggests that assessment should be future oriented. Because development is continually shaped and channeled by transactions between the child and the environment, assessment should be repeated through time. This could take place during the ongoing process of intervention or it could be in the form of intermittent monitoring. The purpose of reassessment is to ensure that the child's occupational development is moving in the desired direction, to detect when new issues related to the child's occupations have emerged, and to re-evaluate intervention or occupational options in order to reformulate the most beneficial plan for helping the child and family, given changes that have occurred. Note that this assessment strategy continues to use a top-down approach, with occupation as the primary reference point, but assessment is not conducted only at one specific point in time. Instead, assessment is ongoing or recurs intermittently as time moves forward.

An implication of bringing a future orientation into clinical assessment is that prevention of

PRACTICE WISDOM

Recently adding part-time clinical practice in an outpatient occupational therapy clinic to my daily activities, I found that each of the four children I was seeing had some features of sensory integrative disorder, including problems with sensory modulation, discrimination, and praxis. For each child, performance of functional skills and participation was impacted by these sensory integrative problems. Some kids had issues with toileting, hair brushing, or sequencing their nighttime hygiene routines, whereas others had difficulty participating with peers in age-level games and sports. However, the goals that had been written previously for each child were focused neither on function nor participation. There were goals for demonstrating in-hand manipulation skills but not for being able to open milk containers at lunch. There were goals for being able to sequence an obstacle course but not goals for being able to sequence the steps needed to brush teeth. And there were goals for improving self-regulation but no mention for how self-regulatory skills would transfer over into being able to play a board game with a friend. I found, in talking to parents, that what they were really hoping their child got out of occupational therapy was much different from established goals. I also found that the kids had expressed goals that weren't reflected in the evaluations or therapy goals—one adolescent noting, "I would just like to be able to make a real friend." In modifying treatment goals to be more function- and participation-focused, I found that I got better buy-in overall from the children and their parents. I enjoyed seeing how working on the children's underlying sensory issues in an outpatient setting could translate into meaningful gains in occupational performance in home, school, and community settings. Take home message: Meaningful goals focus on what children and parents want within the context of their real lives. Theory helps us develop interventions and predict change, but the needs of families and children always take priority over theoretical constructs.

potential problems comes to the forefront. When assessment addresses only concerns related to the present, one's attention is not drawn systematically to information that may signal risk for future problems. A present-only assessment strategy may lead to concluding that a particular child or family will not benefit from intervention because there is limited evidence of an occupational problem at the current time, when, in fact, some assistance or guidance at the present time may avert problems that are likely to emerge in the future. If one is consciously imagining the future occupational life of a child by extrapolating from what is known about present occupational patterns and contexts, as well as the current status of performance components, including SI, it is more likely that risk factors for later occupational difficulties will be identified and that something will be done to minimize or counteract the risk. For example, Kyle, the child featured in Chapter 11 (Interpreting and Explaining Evaluation Data), experienced success in kindergarten, despite sensory integrative dysfunction, because his teacher accommodated so well for his difficulties. However, in evaluation, his family and therapist sought to offset the difficulties they anticipated Kyle having in first grade with a different teacher and when classroom demands increased.

Granted, not much is known about factors that *predict* future problems with a satisfying, productive, and enjoyable work and play life. Additionally, health-care and education systems in much of the world are not prepared to designate funding for large-scale preventive programs. Nevertheless, preventive efforts may be economically advantageous in the long run. Perhaps future research will identify powerful early predictors of occupational problems in childhood, adolescence, and adulthood. We may find that there are times when screening or assessment of functions, such as SI, is appropriate for preventive purposes, as when children are screened for vision or hearing problems so that intervention can be introduced before such problems have adverse effects on school performance (Fig. 2-5). For example, Thomas and colleagues (2015) found preliminary evidence that they could predict the development of sensory over-responsiveness in childhood using the presence of feeding and sleep difficulties of young infants as a proxy. They hypothesized that early identification and intervention could minimize the impact of the sensory difficulties on attachment, emotion regulation, and, later, engagement in play, self-care, sleep, and school participation.

Possibly intervention aimed at minimizing the impact of sensory difficulties at a young age may

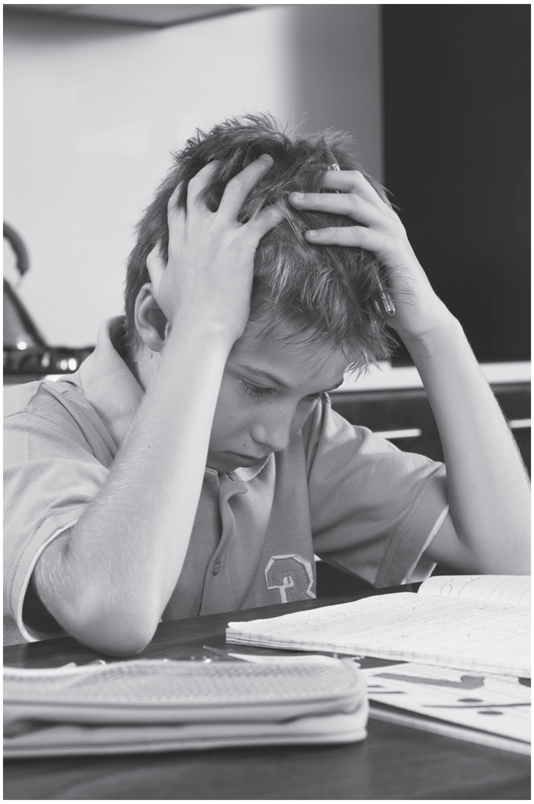

FIGURE 2-5 Children with praxis problems in early childhood are at risk for academic problems later on. *Image courtesy Thinkstock/jupiterimages.*

maximize children's later occupational participation. Ultimately, this use of performance components for anticipating difficulties is directed toward enhancing the future occupational life of the child; therefore, we can think of it as a top-down approach in which the top is projected into the future. Even though research is limited and we must keep in mind the limitations of the existing research, occupational therapists can incorporate estimations of risk into their assessments by imagining where the child and family might end up in the future if they continue on their current course.

In considering how to minimize child and family risk, occupational therapists need to consider all potential resources available to the child or family. For example, we have evidence (Reynolds, Lane, & Thacker, 2011) that sensory modulation difficulties in early childhood are strongly associated with sleep disorders, particularly in children with ASD. Occupational therapists can contribute to intervention programs for children with ASD by sharing this information with families whose children with ASD have sensory overresponsiveness and helping them to develop family strategies that promote healthy sleep patterns by creating soothing environments and predictable bedtime routines. We also have evidence (Parham, 1998) that praxis difficulties in early childhood place a child at risk for later academic problems, especially in mathematics. Occupational therapists working with young children with dyspraxia may want to share this information with parents and help them plan ways to give the child additional support for academic skill development before the child experiences repeated failure. Referrals to social workers, psychologists, other professionals, family and child-care service providers, and community children's programs also can be important for connecting families with resources that can help minimize risk.

Consideration of Intervention Options

The multidimensionality of occupation and its enmeshment with environmental **contexts** suggests that many options for intervention should be considered if clinical assessment indicates that a child is experiencing difficulty with occupations. The occupational therapist's challenge is to identify variables that can be altered in order to affect a positive change in the entire system comprising a child's transactions with his or her environment and to envision how a process of change might unfold through time. Then intervention options are selected and orchestrated to channel the child's and family's occupations in a direction that will move them toward achieving the desired occupational goals.

When sensory integrative difficulties contribute to a child's occupational problems, the occupational therapist must consider whether intervention should focus on altering the child's ability to participate in occupations, on changing the child's experience by altering aspects of the environment to support the child's engagement, or on some combination of these strategies. If improvement in sensory integrative abilities is desirable, then individual occupational therapy using an Ayres SI approach should be given the first consideration, as evidence of its effectiveness is supported by several well-designed randomized clinical trials (Miller, Coll, & Schoen, 2007; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2014). Alternatively, or in conjunction with individual therapy, it may be helpful to encourage the family to advocate for school-based group programs (e.g., Hartshorn et al., 2001; Koenig, Buckley-Reen, & Garg, 2012) or enroll the child in enrichment programs that are available in the community, such as gym classes or swimming. If the child has significant sensory modulation issues, perhaps a program that helps the child develop strategies to cope better with everyday routines and environments (e.g., the Alert Program; Williams & Shellenberger, 1996; see also Chapter 20, Planning and Implementing Intervention Using Sensory Integration Theory) would be beneficial. If specific motor or social skills are key problems, then skill training, either individually or in a group, might be appropriate. Is immediate success in troublesome occupations an urgent need? If so, consultation or coaching to suggest changes in tasks or activities and their environmental contexts may be the priority (see also Chapter 17, Using Sensory Integration Theory in Coaching). Dunbar (1999) and Bundy and Green (see Chapter 22, Viewing Intervention Through Different Lenses) provided relevant case examples. Alternatively, occupational therapists may collaborate with families to organize their lifestyles so that sensory needs and interests of children are integrated into daily family routines at the same time that parental needs, interests, occupational styles, and values are accommodated (Dunn, 2014; Dunn, Cox, Foster, Mische-Lawson, & Tanquary, 2012).

Consideration of family and child resources, preferences, and occupational styles, as well as community resources, is critical in recommending and discussing intervention options with families. When considering how to be most helpful to a child and family, it is useful to imagine the transactional process of development projecting into the future. Who is this child becoming? Where are the lives of the child and family headed? What resources are available to them? How supportive is the environment? How might the trajectory be altered if various intervention options are introduced?

HERE'S THE POINT

- Assessment using the SI approach should take into account the complex, transactional nature of participation in everyday activities, including strengths and resources available.
- SI approaches should address goals that reflect the values and needs of the child and family, are focused on function and participation, and reflect outcomes that are evidence-based.

Summary and Conclusions

From its inception, SI theory has viewed the child as an active agent in the world, whose engagement with the environment affects the development of competence and satisfaction in doing occupations. Within this theory, the neurobiological construct of SI holds an important position as a mediator between the child's physical self and the external world. Because the neural processes and behavioral expressions of SI shape the person's capacity and willingness to act on the environment, SI is relevant to the construction of the self through the doing of occupations.

However, SI is only one of many factors that influence occupation; it interplays with social expectations, physical environments, and personal experiences in shaping an individual's occupational life. (See also Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited.) We have evidence that sensory integrative characteristics influence the person's competencies in doing various activities as well as personal choices of occupations and how to perform them, throughout the life span.

The reciprocal relationship between SI and occupation opens the door to a multitude of intervention possibilities. Because SI affects engagement in occupations, it is one of the many factors that may be considered in assessing the reasons for why a child may be experiencing difficulties with occupations, such as participating in home, school, and play activities. One valuable, evidence-based course of action for intervention is to strengthen sensory integrative capacities through provision of individual Ayres Sensory Integration® (ASI) intervention. An additional option is to use knowledge of a child's SI strengths and limitations to modify the tasks, routines, and environments of the child's occupational life in order to maximize the child's success and family satisfaction in the immediate contexts of daily life. Several researchers (e.g., Bulkeley, Bundy, Roberts, & Einfeld, 2016; Dunn et al., 2012; Kientz & Dunn, 2012) have had some degree of success with context-based interventions. Future research also may assist us in evaluating the extent to which sensory integrative abilities can be developed through community-based activity programs, such as classes in creative movement, yoga, swimming, or other physical activities. Research remains to be done to clarify when particular approaches are most beneficial, for whom, and under which circumstances.

SI is not simply a neurological process contained entirely within the individual. It is a complex process through which the nervous system mediates transactions between individuals and the world. In this view, SI serves as a scaffold for human agency and, therefore, is linked inextricably with occupation.

Where Can I Find More?

Schaaf, R., & Mailloux, Z. (2015). *Clinician's Guide to Implementing Ayres Sensory Integration®: Promoting Participation for Children with Autism.*

A step-by-step guidebook that describes the most effective, evidence-based way to implement ASI into clinical practice by using a data-driven decision-making approach.

DeMonia, L., & Turchan, M. (2015). *Love for Logan.* San Antonio, TX: Halo Publishing International.

An inspirational story based on actual events. A young girl learns to better understand why day-to-day life can be challenging for her older sister. A kid-friendly picture book, told through the eyes of a sibling, will help children understand others' sensory difficulties, and explain sensory processing disorder.

Bialer, D., & Miller, L. J. (2011). *No Longer A SECRET*: Unique Common Sense Strategies for Children with Sensory or Motor Challenges. Arlington, TX: Sensory World.

A resource for parents, teachers, and therapists helping children with sensory or motor issues. It includes cost-effective, functional, on the spot tips to use for children with sensory issues at home, at school, or in a community setting.

References

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (2004). *Sensory integration and the child* (2nd ed.). Los Angeles, CA: Western Psychological Services.

Bagby, M., Dickie, V., & Baranek, G. T. (2012). How sensory experiences in children with and without autism affect family occupations. *American Journal of Occupational Therapy*, *66*, 78–86. doi:10.5014/ajot.2012.000604

Baranek, G. T., Chin, Y. H., Hess, L. M. G., Yankee, J. G., Harton, D. D., & Hooper, S. R. (2002). Sensory processing correlates of occupational performance in children with Fragile X syndrome: Preliminary findings. *American Journal of Occupational Therapy*, *56*, 538–546. doi:10.5014/ajot.56.5.538

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry*, *47*(6), 591–601. doi:10.1111/j.1469-7610.2005.01546.x

Bellefeuille, I. B., Schaaf, R. C., & Polo, E. R. (2013). Occupational therapy based on Ayres Sensory Integration in the treatment of retentive fecal incontinence in a 3-year-old boy. *American Journal of Occupational Therapy*, *67*(5), 601–606. doi:10.5014/ajot.2013.008086

Benson, J., Nicka, M., & Stern, P. (2006). How does a child with sensory processing problems play? *Internet Journal of Allied Health Sciences and Practice*, *4*, 1–6.

Blissett, J., & Fogel, A. (2013). Intrinsic and extrinsic influences on children's acceptance of new foods. *Physiology & Behavior*, *121*, 89–95. doi:10.1016/j.physbeh.2013.02.013

Brown, T. (2012). Assessment, measurement and evaluation: Why can't I do what everyone expects me to do? In S. J. Lane & A. C. Bundy (Eds.), *Kids can be kids: A childhood occupations approach* (pp. 320–348). Philadelphia, PA: F.A. Davis.

Bulkeley, K., Bundy, A., Roberts, J., & Einfeld, S. (2016). Family-centered management of sensory challenges of children with autism: A single-case experimental design. *American Journal of Occupational Therapy*, *70*, 7005220040. doi:10.5014/ajot.2016.017822

Bundy, A. C. (1989). A comparison of the play skills of normal boys and boys with sensory integrative dysfunction. *OTJR: Occupation, Participation, and Health*, *9*, 84–100.

Bundy, A. C., Shia, S., Qi, L., & Miller, L. J. (2007). How does sensory processing dysfunction affect play? *American Journal of Occupational Therapy*, *61*, 201–208. doi:10.50144/ajot.61.2.201

Christensen, J. S. (2012). Early adolescent non-suicidal self-injury and sensory preference differences: An exploratory study. *CGU Theses & Dissertations*, Paper 66. Retrieved from http://scholarship.claremont.edu/cgu_etd/66

Clifford, J. M., & Bundy, A. C. (1989). Play preference and play performance in normal boys and boys with sensory integrative dysfunction. *OTJR: Occupation, Participation, and Health*, *9*, 202–217.

Cohn, E. S., Kramer, J. A., Schub, J. A., & May-Benson, T. (2014). Parents' explanatory models and hopes for outcomes of occupational therapy using a sensory integration approach. *American Journal of Occupational Therapy*, *68*, 454–462. doi:10.5014/ajot.2014.010843

Cosbey, J., Johnston, S. S., & Dunn, M. L. (2010). Sensory processing disorders and social participation. *American Journal of Occupational Therapy*, *64*(3), 462–473. doi:10.5014/ajot.2010.09076

Cosbey, J., Johnston, S. S., Dunn, M. L., & Bauman, M. (2012). Playground behaviors of children with and without sensory processing disorders. *OTJR: Occupation, Participation, and Health*, *32*, 39–47. doi:10.3928/15394492-20110930-01

Coster, W. (1998). Occupation-centered assessment of children. *American Journal of Occupational Therapy*, *52*, 337–344. doi:10.5014/ajot.52.5.337

Davis, A. M., Bruce, A. S., Khasawneh, R., Schulz, T., Fox, C., & Dunn, W. (2013). Sensory processing issues in young children presenting to an outpatient feeding clinic: A retrospective chart review. *Journal of Pediatric Gastroenterology and Nutrition*, *56*(2), 156. doi:10.1097/mpg.0b013e3182736e19

DeSantis, A., Coster, W., Bigsby, R., & Lester, B. (2004). Colic and fussing in infancy, and sensory processing at 3 to 8 years of age. *Infant Mental Health Journal*, *25*(6), 522–539. doi:10.1002/imhj.20025

Dunbar, S. B. (1999). A child's occupational performance: Considerations of sensory processing and family context. *American Journal of Occupational Therapy*, *53*, 231–235. doi:10.5014/ajot.53.2.231

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and families: A conceptual model. *Infants and Young Children*, *9*, 23–25. doi:10.1097/00001163-199704000-00005

Dunn, W. (2014). *Sensory Profile 2: User's manual*. San Antonio, TX: Psychological Corporation.

Dunn, W., Cox, J., Foster, L., Mische-Lawson, L., & Tanquary, J. (2012). Impact of a contextual intervention on child participation and parent competence among children with autism spectrum disorders: A pretest–posttest repeated-measures design. *American Journal of Occupational Therapy*, *66*(5), 520–528. doi:10.5014/ajot.2012.004119

Engel-Yeger, B., & Dunn, W. (2011a). Exploring the relationship between affect and sensory processing patterns in adults. *British Journal of Occupational Therapy*, *74*(10), 456–464. doi:10.4276/030802211x13182481841868

Engel-Yeger, B., & Dunn, W. (2011b). The relationship between sensory processing difficulties and anxiety level of healthy adults. *British Journal of Occupational Therapy*, *74*(5), 210–216. doi:10.4276/030802211x13046730116407

Engel-Yeger, B., & Shochat, T. (2012). The relationship between sensory processing patterns and sleep quality in healthy adults. *Canadian Journal of Occupational Therapy*, *79*(3), 134–141. doi:10.2182/cjot.2012.79.3.2

Esdaile, S. A., & Olson, J. A. (2003). *Mothering occupations*. Philadelphia, PA: F. A. Davis.

Fanchiang, S.-P. (1996). The other side of the coin: Growing up with a learning disability. *American Journal of Occupational Therapy*, *50*, 277–285. doi:10.5014/ajot.50.4.277

Fanchiang, S.-P., Snyder, C., Zobel-Lachiusa, J., Loeffler, C. B., & Thompson, M. E. (1990). Sensory integrative processing in delinquent-prone and non-delinquent-prone adolescents. *American Journal of Occupational Therapy*, *44*(7), 630–639. doi:10.5014/ajot.44.7.630

Fisher, A. G. (1998). Uniting practice and theory in an occupational framework. The 1998 Eleanor Clark Slagle lecture. *American Journal of Occupational Therapy*, *52*, 509–521. doi:10.5014/ajot.52.7.509

Fisher, A. G., & Marterella, A. (2019). *Powerful practice: A model of authentic occupational therapy*. Fort Collins, CO: Innovative Occupational Therapy Practice.

Fisher, A. G., & Short-DeGraff, M. (1993). Improving functional assessment in occupational therapy: Recommendations and philosophy for change. *American Journal of Occupational Therapy*, *47*, 199–200. doi:10.5014/ajot.47.3.199

Geva, R., & Feldman, R. (2008). A neurobiological model for the effects of early brainstem functioning on the development of behavior and emotion regulation in infants: Implications for prenatal and perinatal risk. *Journal of Child Psychology and Psychiatry*, *49*(10), 1031–1041. doi:10.1111/j.1469-7610.2008.01918.x

Grandin, T. (2006). *Thinking in pictures: My life with autism* (2nd ed.). New York, NY: Vintage Books.

Gray, J. M. (1998). Putting occupation into practice: Occupation as ends, occupation as means. *American Journal of Occupational Therapy*, *52*, 354–364. doi:10.5014/ajot.52.5.354

Green, S. A., & Ben-Sasson, A. (2010). Anxiety disorders and sensory over-responsivity in children with autism spectrum disorders: Is there a causal relationship? *Journal of Autism and Developmental Disorders*, *40*, 1495–1504. doi:10.1007/s10803-010-1007-x

Greene, K., Krcmar, M., Walters, L. H., Rubin, D. L., & Hale, L. (2000). Targeting adolescent risk-taking behaviors: The contributions of egocentrism and sensation-seeking. *Journal of Adolescence*, *23*(4), 439–461. doi:10.1006/jado.2000.0330

Hartshorn, K., Olds, L., Field, T., Delage, J., Cullen, C., & Escalona, A. (2001). Creative movement therapy benefits children with autism. *Early Child Development and Care*, *166*, 1–5. doi:10.1080/0300443011660101

Hilton, C., Graver, K., & LaVesser, P. (2007). Relationship between social competence and sensory processing in children with high functioning autism spectrum disorders. *Research in Autism Spectrum Disorders*, *1*(2), 164–173. doi:10.1016/j.rasd.2006.10.002

Hochhauser, M., & Engel-Yeger, B. (2010). Sensory processing abilities and their relation to participation in leisure activities among children with high-functioning autism spectrum disorder (HFASD). *Research in Autism Spectrum Disorders*, *4*(4), 746–754. doi:10.1016/j.rasd.2010.01.015

Hofer, M. A. (2006). Psychobiological roots of early attachment. *Current Directions in Psychological Science*, *15*(2), 84–88. doi:10.1111/j.0963-7214.2006.00412.x

Jerome, E. M., & Liss, M. (2005). Relationships between sensory processing style, adult attachment, and coping. *Personality and Individual Differences*, *38*(6), 1341–1352. doi:10.1016/j.paid.2004.08.016

Kientz, M., & Dunn, W. (2012). Evaluating the effectiveness of contextual intervention for adolescents with autism spectrum disorders. *Journal of Occupational Therapy, Schools, & Early Intervention*, *5*(3–4), 196–208. doi:10.1080/19411243.2012.737271

Kimball, J. G., Birstler, C. T., Bosse, E. F., Nelson, L. M., & Woods, M. R. (2012). The relationships among sensory processing styles, personality traits, and body mass index: A pilot study. *Occupational Therapy in Mental Health*, *28*(1), 72–87. doi:10.1080/0164212x.2012.650994

Kinnealey, M., Koenig, K. P., & Smith, S. (2011). Relationships between sensory modulation and social supports and health-related quality of life. *American Journal of Occupational Therapy*, *65*(3), 320–327. doi:10.5014/ajot.2011.001370

Kinnealey, M., Oliver, B., & Wilbarger, P. (1995). A phenomenological study of sensory defensiveness in adults. *American Journal of Occupational Therapy*, *49*, 444–451. doi:10.5014/ajot.49.5.444

Koenig, K. P., Buckley-Reen, A., & Garg, S. (2012). Efficacy of the Get Ready to Learn Yoga Program among children with autism spectrum disorders: A pretest-posttest control group design. *American Journal of Occupational Therapy*, *66*, 538–546. doi:10.5014/ajot.2012.004390

Koenig, K. P., & Rudney, S. G. (2010). Performance challenges for children and adolescents with difficulty processing and integrating sensory information: A systematic review. *American Journal of Occupational Therapy*, *64*, 430–442. doi:10.5014/ajot.2010.09073

Lane, A. E., Young, R. L., Baker, A. E., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders*, *40*(1), 112–122. doi:10.1007/s10803-009-0840-2

Leekam, S., Nieto, C., Libby, S., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders*, *37*, 894–910. doi:10.1007/s10803-006-0218-7

Lightfoot, C. (1997). *The culture of adolescent risk-taking*. New York, NY: The Guilford Press.

Mattingly, C., & Fleming, M. (1994). *Clinical reasoning: Forms of inquiry in a therapeutic process*. Philadelphia, PA: F. A. Davis.

McCarter, J. A. (2010). Growing up with sensory processing challenges. *AOTA Special Interest Section Quarterly: Sensory Integration*, *33*(3), 1–2.

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *American Journal of Occupational Therapy*, *61*, 228–238. doi:10.5014/ajot.61.2.228

Miller Kuhaneck, H., & Britner, P. A. (2013). A preliminary investigation of the relationship between sensory processing and social play in autism spectrum disorder. *OTJR: Occupation, Participation and Health*, *33*(3), 159–167.

Mische Lawson, L., & Dunn, W. (2008). Children's sensory processing patterns and play preferences. *Annual in Therapeutic Recreation*, *16*, 1–14.

O'Neil, M. (2010). Parenting a child with sensory integration challenges. *SISQ: Sensory Integration*, *33*(3), 2–3.

Parham, L. D. (1998). The relationship of sensory integrative development to achievement in elementary students: Four-year longitudinal patterns. *Occupational Therapy Journal of Research*, *18*, 105–127.

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy*, *65*, 76–85. doi:10.5014/ajot.2011.09205

Pierce, D. (2009). Co-occupations: The challenges of defining concepts original to occupational science. *Journal of Occupational Science*, *16*, 203–207.

Pohl, P. S., Dunn, W., & Brown, C. (2003). The role of sensory processing in the everyday lives of older adults. *OTJR: Occupation, Participation, and Health*, *23*, 99–106.

Purvis, K. B., McKenzie, L. B., Cross, D. R., & Razuri, E. B. (2013). A spontaneous emergence of attachment behavior in at-risk children and a correlation with sensory deficits. *Journal of Child and Adolescent Psychiatric Nursing*, *26*(3), 165–172. doi:10.1111/jcap.12041

Radzyminski, S. (2005). Neurobehavioral functioning and breastfeeding behavior in the newborn. *Journal of Obstetric, Gynecologic,*

& Neonatal Nursing, *34*(3), 335–341. doi:10.1177/0884217505276283

Reynolds, S., Bendixen, R. M., Lawrence, T., & Lane, S. (2011). A pilot study examining activity participation, sensory responsiveness, and competence in children with high functioning autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *41*, 1496–1506. doi:10.1007/s10803-010-1173-x

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism and Developmental Disorders*, *38*, 516–529. doi:10.1007/s10803-007-0418-9

Reynolds, S., & Lane, S. J. (2009). Sensory over-responsivity and anxiety in children with ADHD. *American Journal of Occupational Therapy*, *63*, 443–450. doi:10.5014/ajot.63.4.433

Reynolds, S., Lane, S. J., & Thacker, L. (2011). Sensory processing, physiological stress, and sleep behaviors in children with and without autism spectrum disorders. *OTJR: Occupational, Participation, and Health*, *32*, 246–257. doi:10.3928/15394492-20110513-02

Sameroff, A. (2009). The transactional model. In A. Sameroff (Ed.), *The transactional model of development: How children and contexts shape each other* (pp. 3–21). Washington, DC: American Psychological Association.

Schaaf, R. C. (2011). Interventions that address sensory dysfunction for individuals with autism spectrum disorders: Preliminary evidence for the superiority of sensory integration compared to other sensory approaches. In B. Reichow, P. Doehring, D. V. Cicchetti, & F. R. Volkmar (Eds.), *Evidence-based practices and treatments for children with autism* (pp. 245–273). New York, NY: Springer.

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., … Kelly, D. (2014). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disabilities*, *44*, 1493–1506. doi:10.1007/s10803-013-1983-8

Shea, C., & Wu, R. (2012). Examining the sensory profiles of at-risk youth participating in a pre-employment program. *The Open Journal of Occupational Therapy*, *1*(1), 5.

Shochat, T., Tzischinsky, O., & Engel-Yeger, B. (2009). Sensory hypersensitivity as a contributing factor in the relation between sleep and behavioral disorders in normal children. *Behavioral Sleep Medicine*, *7*, 53–62. doi:10.1080/15402000802577777

Smyth, M. M., & Anderson, H. I. (2000). Coping with clumsiness in the school playground: Social and physical play in children with coordination impairments. *British Journal of Developmental Psychology*, *18*(3), 389–413. doi:10.1348/026151000165760

Stols, D., Van Heerden, R., Van Jaarsveld, A., & Nel, R. (2013). Substance abusers' anger behaviour and sensory processing patterns: An occupational therapy investigation. *South African Journal of Occupational Therapy*, *43*(1), 25–34.

Thomas, S., Bundy, A. C., Black, D., & Lane, S. J. (2015). Toward early identification of sensory over-responsivity (SOR): A construct for predicting difficulties with sleep and feeding in infants. *OTJR: Occupation, Participation and Health*, *35*, 178–186. doi:10.1177/1539449215579855

Trombly, C. A. (1993). Anticipating the future: Assessment of occupational function. *American Journal of Occupational Therapy*, *47*, 253–257.

Trott, M. C., Laurel, M. K., & Windeck, S. L. (1993). *SenseAbilities: Understanding sensory integration*. Tucson, AZ: Therapy Skill Builders (now ProEd).

Turner, K. A., Cohn, E. S., & Koomar, J. (2012). Mothering when mothers and children both have sensory processing challenges. *British Journal of Occupational Therapy*, *75*(10), 449–455. doi:10.4276/030802212X13496921049626

Watts, T., Stagnitti, K., & Brown, T. (2014). Relationship between play and sensory processing: A systematic review. *American Journal of Occupational Therapy*, *68*, e37–e46. doi:10.5014/ajot.2014.009787

Weiss-Salinas, D., & Williams, N. (2001). Sensory defensiveness: A theory of its effect on breastfeeding. *Journal of Human Lactation*, *17*(2), 145–151. doi:10.1177/089033440101700211

Welters-Davis, M., & Mische Lawson, L. (2011). The relationship between sensory processing and parent-child play preferences. *Journal of Occupational Therapy, Schools, and Early Intervention*, *4*, 108–120. doi:10.1080/19411243.2011.595300

Wiener, A. S., Long, T., DeGangi, G. A., & Battaile, B. (1996). Sensory processing of infants born prematurely or with regulatory disorders. *Physical & Occupational Therapy in Pediatrics*, *16*(4), 1–18.

Williams, M. S., & Shellenberger, S. (1996). *How does your engine run? A leader's guide to the Alert Program for Self-regulation*. Albuquerque, NM: TherapyWorks.

Zemke, R., & Clark, F. (1996). Co-occupations of mothers and children. In R. Zemke & F. Clark (Eds.), *Occupational science: The evolving discipline* (pp. 213–215). Philadelphia, PA: F.A. Davis.

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. Cambridge, UK: Cambridge University Press.

CHAPTER 3

Composing a Theory

An Historical Perspective

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Take criticism seriously, but not personally. If there is truth or merit in the criticism, try to learn from it. Otherwise, let it roll right off you.

— Hillary Clinton

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Recognize how Ayres' personal traits and professional training led to the development of sensory integration (SI) theory.
- ✔ Describe how a community of clinicians and scholars, led by Ayres, emerged and grew the field of SI within occupational therapy.
- ✔ Identify how SI research and practice has evolved while continuing to be grounded in Ayres' original theory.

Purpose and Scope

Ayres' work has been, and continues to be, admired by some and rejected by others. Throughout her professional life she seemed to take both in stride. Although the rejections and misunderstandings were distressing to her, she had learned in childhood how to withdraw into her own mind and to use willpower to get past unhappiness. She worked, studied, and read relentlessly, never certain how much time she would have to complete her life goals (Gorman & Kashani, 2017; Sieg, 1988).

Endeavoring to understand both the history of sensory integration (SI) and current research and practice trends, we interviewed colleagues who had the opportunity to learn, study, and work with Ayres and were influential in shaping SI theory and related concepts. We have also conducted in-depth reviews of related literature. Based on this work, we conclude that, although we have seen evolution, the core construct of Ayres' Sensory Integration® (ASI) theory, linking brain processing with observable behavior, continues to be a focal point in theory and practice.

Here we present a historical account of the evolution of SI theory and practice, drawn from our interviews and readings. We have chosen to acknowledge contributors at the close of the chapter rather than attribute individual comments to individual colleagues.

A Little Background

ASI theory is globally used in pediatric practice, and core constructs are applied across many other areas of practice. This theoretical foundation has engendered much research and collegial discourse, likely more than any other theory in the profession of occupational therapy (May-Benson & Koomar, 2010; Schaaf et al., 2015). SI theory emerged because of Ayres' constant imperative to look beyond behavior and gain an understanding of the neurological underpinnings of disorders, in order to support engagement and participation in the activities of daily life. Blending research with clinical practice, the children with whom Ayres interacted were her motivation to link neuroscience and behavior. An emergent leader around whom people congregated, Ayres embodied the roles of clinician, researcher, and teacher, always encouraging others to do the same.

According to Kielhofner (2004), Ayres' work evolved at a time of "crisis" in occupational therapy. Up to this point, roughly through the 1960s, occupational therapy had focused on the importance of occupation in daily life, using "doing" as therapy. However, the medical field indicated that, although it seemed apparent that engagement in occupation was beneficial, *there was no comprehensive theory and no documented evidence* that occupational therapy was effective (Kielhofner, 2004). Ayres, in the mid- to late 1950s, had begun her work examining proprioceptive facilitation for the upper extremities, with an interest in understanding the underlying mechanisms of both function and dysfunction. Kielhofner suggested that Ayres became part of a newly emerging mechanistic paradigm in occupational therapy, emphasizing that the benefits of engagement in occupation and activity were best explained by understanding the underlying mechanisms. Although Ayres was highly invested in understanding the neurological mechanisms of sensory integrative function and dysfunction, she never lost sight of the bigger picture, that of supporting engagement in childhood occupations (see Fig. 3-1).

Ayres may not have set out to become the "heart" of SI. In fact, accounts suggest that she wanted anything *but* to become the center of this universe; rather, she preferred that there be centers of sensory integrative knowledge all around the world. Nonetheless, she was driven to understand the underpinnings of the disorders she saw clinically. She pursued advanced training in research and neuroscience to guide her growing knowledge of links between neurophysiological mechanisms and clinical practice, and, through time, developed the theory and practice of SI. She became the hub of knowledge about SI. According to Kielhofner (2004), the model of SI became a "conceptual practice model." Such models emerge as a means of explaining phenomena, developing tools for practice, and setting the stage for research on the model. By their very nature, these models are dynamic; they are revised in an organic way as new knowledge develops through both research and clinical application. This is certainly true of SI.

FIGURE 3-1 Ayres, always a clinician, "learning" from a client. *Used with permission by Franklin B. Baker/A. Jean Ayres Baker Trust.*

Ayres the Person

Sieg (1988) summarized Ayres' childhood as one in which she found comfort in being outdoors on the family farm and enjoyed being with her brother and younger sister. Ayres reportedly had a difficult relationship with an older sister as well as her mother, becoming increasingly introverted in response to these relationships. She also grew up dealing with what she saw as a "damaged left hemisphere," which caused her to struggle to understand spoken words, particularly if the speaker had an accent (Sieg, 1988). Although Ayres went on to do a great deal of reading, writing, and speaking, writing and lecturing remained a challenge for her throughout her life

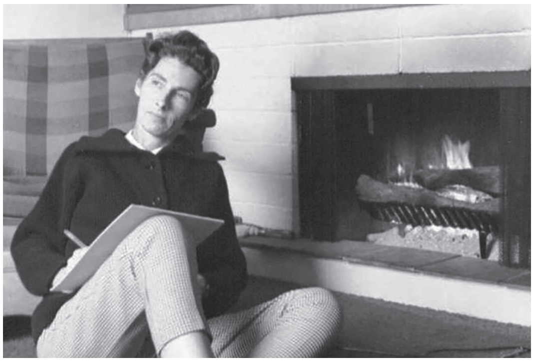

FIGURE 3-2 Although Ayres did not enjoy writing, she knew it was crucial to move her work forward. *Used with permission by Franklin B. Baker/A. Jean Ayres Baker Trust.*

(Fig. 3-2). According to one colleague, Ayres "didn't like lecturing, she didn't like writing, but she had to do it because she wanted to do her research . . . if you ever look at one of her lectures, they're color coded all the way through . . . she needed that coding visually to get her through her lectures."

Only a small number of therapists that we interviewed felt they truly knew Ayres as a person. She was described as ". . . [not] social-social, but she was very relational." Ayres was noted to be amazingly kind and an excellent listener. In spite of what may have been a childhood challenged by many factors (including her own health), Ayres put family, and her husband, Franklin, at the center of her world: "Her family was probably central . . . her family was like her nest and her comfort. That was like a cocoon for her . . . she never really talked about her family or anything. [But] in her writing you can see that was her main core heart of her life. . . ." Her love of family is reflected in *Love, Jean,* published after her death. This compendium of letters between herself and her nephew, Phillip, reflects her love and concern for him as they worked together to treat his sensory integrative disorder, "by remote control," through letters. Her dedication to Franklin became apparent in Sieg's narrative, in which Ayres stated, "I have a nearly perfect, just nearly perfect marriage. Just a real love relationship. A complete pair bond" (Sieg, 1988, p. 96). Ayres' first book, *Sensory Integration and Learning Disorders,* was simply dedicated, "To Franklin."

Ayres the Professional: Developing Her Knowledge Base

Most colleagues that we interviewed offered more insight into Ayres as a therapist and scientist than Ayres on a personal level. Ayres completed her coursework in occupational therapy in 1944 at the University of Southern California (USC), and she performed her clinical internships in 1946, the same year that she successfully passed the occupational therapy registration examination. Working clinically in psychiatry (Birmingham Veterans Hospital, Brentwood Sanatorium) and rehabilitation (Kabat-Kaiser Institute) fueled her already established need for knowledge. Her investment in occupational therapy drove her to investigate underlying components of the disabilities that she saw in her patients; she wanted to better understand the cause so she could better focus the treatment. She began with adults, in rehabilitation, and as such was always invested in a better understanding of neurological functions. In 1949, Ayres first published a paper on craft analysis following electroshock treatments (Ayres, 1949). She became interested in hand functions, publishing on this topic, and her research career bloomed with her master's degree awarded by USC. Her thesis comprised a series of three manuscripts addressing her work on proprioceptive facilitation of the extremities in occupational therapy, published in the *American Journal of Occupational Therapy* in 1955 (Ayres, 1955a, 1955b, 1955c). Ayres had been inspired by her mentor, Margaret Rood. Rood, with degrees in both occupational and physical therapy, was a motor control theorist, one of the first. Rood's focus on reflexes, and her emphasis on the use of proprioceptive inhibition and facilitation, led Ayres to begin her research on the basics of proprioception from a neurological perspective, as well as the application of this basic science information to occupational therapy. In the conclusion of her final paper, Ayres stated:

> It seems, then, that the fundamental organization of the neuromuscular system is based on function. When something disturbs that fundamental organization, it is reasonable to presume that treatment might well be based on function—on activities simulating simple, normal, life-like processes utilizing neurophysiological mechanisms recognized for the integrative role they play. . . . [While] this sounds very logical, it has not been found to be entirely practical.

> This suggests that the treatment of neuromuscular disorders is in the early developmental stages. . . . Treatment procedures will have to adjust accordingly as progress is made. (Ayres, 1955c, pp. 125–126)

Such a statement captures core characteristics that underlie Ayres' subsequent work: a grounding in neuroscience, a focus on the importance of sensation and SI in the production of movement, an appreciation for the importance of engagement in daily life activities including play, and the recognition that there is much to understand related to implementing occupational therapy.

Ayres gained further clinical experience in rehabilitation, and she worked at the United Cerebral Palsy Pre-nursery School and Vocational Training Center before returning to USC to pursue her doctoral degree. In 1955, she joined the Occupational Therapy faculty at USC, continuing there until 1964. While pursuing her PhD in Educational Psychology, completed in 1961, Ayres' interest in the neuroscience of sensory systems moved her toward examining visual spatial abilities and body scheme. During this time, she developed an appreciation of the need for tools that would enable her, and other clinicians, to better understand the role played by perceptual and motor processes in learning. Ayres had developed the Motor Accuracy test before entering her doctoral program, and she went on to focus on other tests of visual perception, developing the Ayres Space Test through her doctoral degree (Gorman & Kashani, 2017). Linking her clinical work with the neuroscience literature led her to a deeper understanding of the integrative nature of sensory processing; Ayres determined that visual perception relied heavily on the processing of vestibular and proprioceptive inputs (Sieg, 1988). "The employing of neural mechanisms to enhance motor development is now well established; the current area of major growth and controversy lies in the use of neurological constructs to aid in understanding and ameliorating cognitive functions such as learning disabilities; the next step may well be a more fruitful attack on emotional and behavior disorders" (Henderson, Llorens, Gilfoyle, Myers, & Prevel, 1974, p. xii). Ayres completed a postdoctoral fellowship at the Brain Research Institute (BRI) at UCLA from 1964 through 1966, where she could study with neuroscientists and expand her thinking on brain function and dysfunction. Although the neuroscientists did not uniformly accept her ideas and perspective, the BRI provided a great learning opportunity and environment for her (Sieg, 1988). During this same time frame, she was working on, and deeply passionate about, her first text, *Sensory Integration and Learning Disorders* (Ayres, 1972). One of Ayres' colleagues indicated the following:

> The quandary of deciding what research to include and what she needed to leave out was something Jean talked about all the time. Whenever Jean talked about this future publication the creative passion that fueled her capacity for work visibly energized her body; her eyes brightened, her face lit up, and everything about her animated. It was amazing and beautiful to watch.

On the heels of completing her postdoctoral fellowship, Ayres returned to USC. However, Ayres reported not being accepted in occupational therapy, indicating "I became so disgusted with occupational therapy in general because I kept wanting to push the field and the field pushed back. . . . I just couldn't tolerate the negativism toward me" (Sieg, 1988, p. 97). Consequently, Ayres initially joined the Department of Special Education; she was later appointed as Adjunct in Occupational Therapy. She opened the Ayres Clinic in Torrance, California, in 1977 and taught the first SI treatment course linked with USC, OT610 (see Fig. 3-3).

By all accounts, Ayres was brilliant, insightful, and committed, and she was considered a mentor by many (see Fig 3-4), as is clearly evident in the following statements from interviewees:

> She was such a wonderful mentor because not only did she have the intelligence to formulize her hypothesis, and it was way out there then, but she designed the equipment; she designed the tests. It was amazing. Plus, she developed her clinical practice to do all the research.
>
> I am still learning from her and if I go back to what she has written it astounds me sometimes. There will be one or two little sentences and I will go, "Oh my God, I missed that." . . . Ayres has informed me about everything really.
>
> There's so much that I learned from her about just how you do science that I mean, it was always with me.
>
> Ayres required that I ask **her** questions during my mentorship with her (1973). She said, "You must question me or you won't be able to question yourself. If you can't question

FIGURE 3-3 Ayres at her clinic. *Used with permission by Franklin B. Baker/A. Jean Ayres Baker Trust.*

FIGURE 3-4 Ayres with Virginia Scardina. Ginny always viewed Ayres as a mentor who guided her clinical career. *Used with permission by Franklin B. Baker/A. Jean Ayres Baker Trust.*

> yourself, you'll never be a researcher." She gave me some really poignant and good advice.

In our interviews, Ayres was described as focused, perhaps driven by her need to understand herself. Ayres was strongly intrinsically motivated in her work, and she appeared never to rest her mind. "One thing Jean always did was read the neurophysiological research. I mean that was primary in her mind when she was looking and developing and thinking in terms of treatment and mechanisms and giving her lectures on theory and all. She was always reading the literature." Although it appeared that Ayres spent a considerable amount of time reading and applying the neurophysiological literature, her interests and knowledge extended well beyond neuroscience. "I learned at that time really how widespread her reading was; I had no idea, I thought she just lived neuroanatomy, not so. So, I found that she was really [widely] read and very experimental and experimented with herself over everything."

Ayres tried many of the activities on herself that she would use eventually with children; "She had problems herself, and so she kind of was analyzing what she felt were underlying things in her and then developed tests to test them. She was that way all the way along." We were told that it was not easy for Ayres to try out her ideas: "One time I said, 'Jean, why are you doing this? How come? It's so hard!' She said, 'Do you think I could stop if I wanted to?' So, it was her inner drive and I learned that about her." Ayres was seen to be in constant search of an answer to her current burning questions and in search of a tool or an approach that would help her focus her own mind. "She was always trying to keep her own brain focused and get the energy out. Then she would come back later, 'Damn, it wore out.' She habituated and it didn't work out as well."

Importantly, Ayres was child-centered in all her interactions with her young clients. In fact, several interviewees commented on her way with children, her deep ability to read their cues and provide the support and challenge they needed to do the things they wanted to do. These perspectives are reflected in the following comments:

> I mean to watch her treat . . . that was something that just really kept striking me because I knew she was this marvelous researcher and test developer and everything, but I think to watch her treat was just a gift because she could

> just pick up exactly what the kid needed at that point in time and do it.
>
> It was how she treated kids and how she interacted with kids, and how she seemed to go deeper with them . . . just watching her treat; her quietness, and the trust that the children had in her. Her presence with the children was pretty amazing, as well as her way of bringing the energy in the room to a just-right level.

In addition to her sensitivity in working with the children, she also had a way with parents. This becomes evident in reading *Love, Jean* (Ayres, 2004) as well as in statements such as the following: "The greatest contribution that I think Ayres has made is helping parents to understand their children's behaviors."

Throughout her career, Ayres mentored hundreds of practitioners, researchers, and theorists, and she influenced countless more. Essentially, against her will, Ayres became a transformational leader (Northouse, 2015), leading by example, inspiring and motivating others to create change in the field of occupational therapy. She enjoyed interaction with therapists who asked questions, therapists who she could see thinking. We were told, "She liked people asking, questioning, and not believing her . . . not swallowing hook, line, sinker." Before her untimely death in 1988, Ayres had presented widely on SI, and she had published several manuscripts linking clinical and research findings, as well as several book chapters, two distinctive texts, and two full assessment batteries.

HERE'S THE POINT

- ASI theory is based on linking observable behavior with neural underpinnings to support engagement and participation.
- Ayres did not set out to be a famous scholar but was driven by her desire to understand herself and her work.
- Ayres' teaching and mentorship of clinicians and scholars has helped her theory evolve and has created widespread change in the field of pediatric occupational therapy.

Growth of Sensory Integration Theory and Research

Until 1971, Ayres had been able to get private and federal funding for her work. Even in the 1970s, obtaining grant funding was no small feat, so this accomplishment needs to be acknowledged. It is quite likely that Ayres' ability to obtain funding was related to her research focus grounded in hard science. However, once this support ceased, Ayres knew she still needed to do research and that it would require funding.

Research and the Center for the Study of Sensory Integrative Dysfunction

In conjunction with colleagues, Dottie Ecker and Sue Knox, Ayres began to generate research dollars from teaching endeavors; by and large in these early days, income from courses was managed on an informal basis, with courses run by a small committee. The initial courses focused on perceptual motor skills rather than SI. Ayres was the primary lecturer, although she was joined by such figures as Margaret Rood and, gradually, by other presenters, such as Knox and Ecker. Aside from academic contributions, Knox reported that she and Ecker also brought "goodies" for course participants. As the teaching grew, the core group decided to form a nonprofit organization into which funds from courses could be placed and subsequently used to support research. In 1972, with private funding, Ayres formally established the Center for the Study of Sensory Integrative Dysfunction (CSSID). Lawrene Kovalenko spearheaded the establishment of CSSID, with the crucial support of Sue Knox and Dottie Ecker. According to Knox, Pat Wilbarger and Ayres were among the original trustees, and the Education Committee consisted of Dottie Ecker, Mary Silberzahn, and Maryann Rinsch. Rinsch resigned soon after the establishment of CSSID, leaving an opening that Knox filled. In addition to the large private donation that Ayres secured for research, there were other contributions. Sharon Cermak indicated she wrote the first check to CSSID, for $25, and in 1975 Judy Kimball sponsored Ayres to do a conference in Syracuse, New York, yielding more than $8,500 in proceeds for CSSID, much to Ayres' appreciation and delight. Although establishment of a center did not sit well with Ayres, she felt it was necessary to support ongoing research.

Although CSSID started small, the demand for courses grew such that additional teaching faculty were recruited beginning in 1974.

FIGURE 3-5 Ayres teaching OT610 in the Ayres Clinic. *Used with permission by Franklin B. Baker/A. Jean Ayres Baker Trust.*

Simple courses morphed into conferences with a certificate of attendance; these would morph again into workshops leading to certification. The certification process required additional faculty and, from this need, faculty training developed. The first training was held in 1976, and gradually the faculty ranks grew. During training, faculty listened to presentations related to theory and testing, and Ayres shared case studies and aspects of her current work (Fig. 3-5). Many therapists currently associated with SI, as well as therapists currently more closely associated with sensory-based and complementary interventions, had their start with CSSID. All contributed to the dissemination of SI theory and practice and, to some extent, to its research base. Faculty met yearly, sharing developing knowledge. One colleague reflected, "We were literally a think tank, and not only did we talk about teaching the course, we also talked about theory and treatment. We talked about the research."

In these early years, there were great learning opportunities and a great deal of sharing among faculty. The need for courses continued, and the number of CSSID faculty grew. Therapists around the country applied, or were invited, to join this perceived "elite" group of instructors. Not everyone who wanted to be part of the faculty was included, and some individuals maintain they were actively discouraged or even blackballed from becoming faculty. At some point there was a moratorium on adding additional faculty, creating a sense of those who were "in" and those who were not, fostering unrest and potentially adding fuel to a smoldering fire.

In 1983, CSSID became Sensory Integration International (SII). This was reportedly prompted because there was increasingly ". . . big international interest . . . some of the faculty being international [e.g., Canadians] . . . and they wanted more of . . . a name that didn't sound so small and isolated. . . ." The name change was not a point of contention; faculty supported the need to have a name that captured their growing international presence.

SII and Growing Tension

Courses offered by SII were doing well, and the Ayres Clinic appeared to be thriving. However, Ayres, the reluctant but admired leader, was battling cancer for the second time in her short life. When she received the second diagnosis, she began to withdraw from activities not directly related to completing the *Sensory Integration and Praxis Test* (SIPT; Ayres, 1989). Perhaps in response to the impending loss of Ayres and her separation from the role of "leader," colleagues began to move in different directions. According to Ballinger (2007), this is to be expected with leader succession. The response of members within the group varies depending on their relationship with the leader. Ballinger indicated that responses of those closest to the leader likely include loyalty, respect, and high levels of affect, whereas individuals farther from the core find themselves less affectively influenced by the impending loss. With regard to the field of SI, this appears to be a time when many sensory-integration-informed, but more sensory-based, therapies began to develop, and when schisms among and between individuals and groups became more apparent.

With her illness, Ayres planned to sell the Ayres Clinic, offering it first to USC. Although the Occupational Therapy Department seriously considered the purchase, it did not happen, and in 1985 SII purchased the Ayres Clinic. USC Professor Florence Clark became the director, maintaining the strong link with USC until 1989 when she resigned to concentrate on the establishment of the Occupational Science PhD program. This was something that "Jean would have wanted, that her clinic would be associated with the university and led by a prominent scholar with a

PhD." Others who had long been associated with both OT610 and the Ayres Clinic (Parham and Mailloux) maintained their roles.

Unfortunately, SII administrative leadership at this time was somewhat divisive and unstable. Following removal of one director, there was a period when things went well; "[Steve Leinau] came in . . . and he put [SII] on the map. He began doing international conferences, and the first one I went to was Marian Diamond and Temple Grandin and not a lot of people knew about them then. So, he started doing conferences, started publishing and doing all that, for about 2½ years. . . ." Steve moved on, and a series of executive directors passed through the organization, one who provided stability and forward momentum, and others who had considerably less positive influence, possibly engaging in unethical practice. The SIPT was published in 1988; new certification courses were introduced; and practitioners were required to retool, another source of tension. Several changes took place in the SII Board of Directors through the ensuing years, and power appeared to shift. There was a sense that some members of the Board had an agenda that was not consistent with the direction of the organization; "They kind of had other interests as well, sensory integration and not strict areas of SI kind of things. . . . They started micromanaging the clinic . . . telling . . . the group what they could do and they couldn't do and everything else." Differences developed between clinicians in the Ayres Clinic and members of the Board of Directors relative to the clinical application of SI, with the board supporting what would be termed "sensory-based" approaches and the clinic therapists feeling that this deviated too far from the core principles of SI. Following what was described as "a very uncomfortable meeting for everybody," the clinicians who had been involved with the Ayres Clinic for years left en masse. This proved problematic for SII as the clinic had been a major source of revenue; the majority of clients from the clinic followed the clinicians, leaving no one to run it and a limited clientele. Attempts to bring in clinicians to bolster the clinic failed. In addition, courses began to falter; course quality was seen to be diminishing; course attendees became disgruntled as courses were scheduled and cancelled; the certification process suffered; and teaching faculty withdrew. In the end, Western Psychological Services withdrew its support for the certification process, instead backing USC and OT610, which was being offered through the re-established clinic, Pediatric Therapy Network.

In our interviews, we had talked with therapists who had been in the central core of Ayres' influence and work, as well as those who were increasingly more removed from her immediate sphere. Through these discourses we were able to get a general sense of the process, some insight into the impact on SI theory and ongoing development of knowledge, but little agreement as to exact timing or cause and effect relative to unfolding tensions. Clearly, Ayres was aware of developing discontent among the SII teaching faculty. They were a group of independent thinkers, and this appeared to lead to multiple disagreements. We were told, "she knew she had not prepared the field for her leaving. And that when she left, because of such strong belief systems, it [teaching faculty] was gonna divide into at least two factions. . . . [There was] bad blood between them, and . . . nobody was willing to compromise or see it as a research issue. . . . [Disagreements] were about personalities and not about research, and she didn't know what to do." Another interviewee stated an alternative impression, indicating that, having heard someone other than Ayres conduct an SI lecture, Ayres responded, "I think things are gonna be in good hands."

Perspectives on the directions taken after Ayres' death vary. We were told, "I think it gave us all an extra impetus to carry on her legacy. . . . And I think people really had a feeling that we wanted to really carry on Jean's legacy." Another interviewee indicated, "Different people took different pieces and tried to advance theory . . . and practice. . . . That's not a criticism. I think there was a lot there that you could take and develop," indicating that individuals took "branches" of the theory and practice to move them forward. For instance, applying the theory to populations of children other than those with learning disabilities was one "branch," formalizing clinical observations another, and specific prescribed interventions (e.g., Therapressure Program) was yet another.

We wondered whether everyone saw growing tension, and many people saw a "fray"; most commented that they tried hard to stay out of it, not wanting to take sides: "I tried to stay out of it as much as possible"; "I saw it as somewhat 'political.'" "I stayed out of what I saw as a 'political mess.'" Generally, these individuals did not necessarily see anything wrong with the various directions people went. One interviewee saw the work of Miller and colleagues in developing the Scientific Workgroup and encouraging and facilitating research funding for colleagues from a variety of disciplines as highly positive. "Lucy Jane Miller and that group that the Wallace [Research] Foundation funded has had tremendous impact on sensory integration . . . people studying it from a wide variety of disciplines and publishing . . . would never have happened without an OT working within that group. . . . Aligning ourselves with people like that makes a big difference. . . . I think the intent was to help to get us accepted by other professionals and disciplines." However, other scholars expressed concern that the different directions would eventually lead to confusion. This concern centered around a shift in terminology from what had been "SI" to what Miller was calling "sensory processing."

The use of different terminology was seen as both positive and negative. On one hand, the shift to sensory processing addressed the concern of some that SI, as used by occupational therapists, was not a term that was universally accepted and understood. "So, by using a term that psychologists were more comfortable with, they had been using [the phrase] sensory processing regulatory disorders already, . . . we would be more accepted. I think that has actually happened."

Others saw it as a potential source of misunderstanding. The lack of clarity relative to defining SI and sensory processing was substantial. Some scholars saw SI as the overall function, and they included sensory processing as a component of SI. Other scholars saw the opposite, with sensory processing as the umbrella term, within which SI was a component. Unfortunately, this conundrum continues to the present.

One interviewee suggested that, with this level of confusion, we would do best to dispense with labels altogether, using descriptive language instead:

> . . . the language is still confusing, haven't made much progress at all with language . . . may be more useful to describe the behaviors that we see. For example, rather than the term sensory modulation, let's just say over-reactivity to sensation, or under-reactivity. . . . Let's just describe the behavior and stop trying to label it until we understand it better.

We heard this call for a better understanding, for stronger science and research, and a new wave of well-educated young scientists in several interviews.

Terminology was an ongoing issue in our interviews. In part, the concern was regarding use of the term *sensory integration* to describe an intervention that we, in this book, have termed *sensory-based.* We have included several sensory-based interventions in Chapter 18 (Complementary Programs for Intervention). Approaches such as The Wilbarger Approach to Treating Sensory Defensiveness, Therapeutic Listening®, and the Astronaut Training Program have a foundation in understanding how sensation is received, processed, and integrated to produce environmental interaction, and here we include them as sensory-based. The treatment approaches described in these programs are missing some of the essential features of what is now called **Ayres Sensory Integration® (ASI).** In fact, the trademarked symbol that now stands at the end of "Ayres Sensory Integration" was a response to what some saw as misappropriation of Ayres' name and work. Calling these approaches SI was seen by some of our interviewees as problematic in terms of theory development: "[this] has big consequences for the evolution of the theory, these things calling themselves sensory integration, but not being sensory integration." It is also seen as posing problems and confusion for teaching and clinical practice.

> We get parents that say they want the brushing protocol and we say, "No, we don't do that, but this is what we will do." . . . It makes it harder to teach some of the real SI kind of stuff because people pull in . . . those kinds of things. And, in some cases . . . when we're teaching . . . and we tell 'em to come up with some treatment strategies and sometimes the first thing is brushing, and I think, "where did we miss out?" And, so, it makes it harder. So, in some ways, I think it can be harmful. It makes it harder for . . . whoever's trying to teach what we're trying to get across.

Another point of ongoing contention has been around the application of the phrase *sensory processing disorder.* As the umbrella term in the nosology (Miller, Anzalone, Lane, Cermak, & Osten, 2007), this phrase encompassed both sensory modulation disorders and praxis disorders. However, as the term was applied to the efforts toward inclusion in the *Diagnostic and Statistical Manual of Mental Disorders,* Fifth Edition *(DSM-5),* the focus was on sensory modulation. The medical field had, at least partially, embraced the construct of regulatory sensory disorder (Miller, Lane, Cermak, Anzalone, & Osten, 2005), and many of the constructs of praxis were already included in the developmental motor coordination diagnostic category. Sensory processing disorder did not get accepted as a diagnosis in the *DSM-5;* however, "hyper-responsivity," "hypo-responsivity," and "unusual interests in sensory aspects of the environment" were included in the criteria for autism (American Psychiatric Association, 2013). The *DC: 0-5™* (Zero to Three, 2016) uses the term *sensory processing disorder* to encompass sensory over- and under-responsiveness, as well as sensory seeking. As such, the issue with clarity on this phrase remains, and it provides another point of tension among SI scholars.

> I think when you're talking about the language, using the term sensory processing, which is mostly about sensory modulation, versus sensory integration, has confused people and led them to believe that it's all about modulation.

Another commented,

> It's kind of interesting to see how it all plays out, but students don't get it, and they think that SI is just sensory modulation but then you should add in some fine motor activities, and a little bit of this and a little bit of that. But that isn't modulation; that is really looking at praxis, and they don't understand the praxis piece.
>
> [Ayres] had developed a SIPT, which was a Sensory Integration and Praxis Test, and all of a sudden the only thing we were talking in the '90s was about modulation . . . it was like we had left some of the praxis out of the study and everything was modulation . . . some of the models on modulation were confusing for most of the people. So, I think that we derailed for many reasons.

The tensions regarding developing branches and terminology issues have not dissipated to any substantial degree at the time of this writing. Relative to "branches" we have tried to capture those sensory-based therapeutic approaches in Chapter 18 (Complementary Programs for Intervention); we recognize that many of these approaches have roots in Ayres' theory of SI. Further, we have decided in this book to use SI to reflect the theoretical and therapeutic foundation developed by Ayres, covering sensory modulation, **sensory discrimination,** and praxis; this is reflected in our model, presented in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited). However, there are times when contributors preferred the term *sensory processing* and we have left this terminology as is.

HERE'S THE POINT

- The CSSID (eventually renamed SII) was a nonprofit organization formed to support SI research via revenue generated from teaching.
- Ayres' illness and withdrawal from both SII and the Ayres Clinic resulted in a lack of leadership and discord among members.
- Terminology around SI theory, intervention, and classification of disorders has been an ongoing point of contention among leaders in the field.

Evolution of Ayres' Work

Through time, Ayres' theory and models have been revisited and adapted by others, as reflected in many of the comments noted previously. These adaptations were fueled by several motivations. Some colleagues (Fisher & Murray, 1991) sought to capture and expand on SI in ways consistent with Ayres' writing but not specifically depicted in her models. Others (e.g., see Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited; Miller, Anzalone, et al., 2007) sought to clarify links between sensory integrative processes and clinical findings and behavior, sometimes in an attempt to simplify Ayres' models and make them more readily available outside the field (Miller, Anzalone, et al., 2007). Still others (e.g., Dunn, 2014) focused on and augmented particular aspects of Ayres' theory. In fact, so many new models have been created that practitioners, and indeed researchers, often seem confused about what constitutes SI theory. Has one or more new theories emerged? Based on our interviews and our review of various published models, the answer to this question is, decidedly, "*NO!*" As noted earlier, one of the people we interviewed suggested "branches," and this analogy seems fitting. Many of our SI scholars have expanded their own work into particular areas of interest, extending the model of SI and at times coupling it with other theoretical models in their efforts to best serve children and families. However, there remains a core; even as available neuroscience knowledge has ballooned, the inferences drawn and hypotheses put forward by Ayres have been shown to be amazingly accurate. The core constructs of Ayres' SI theory, linking brain processing and observable behavior, have remained remarkably stable.

We discuss some of the different published models, endeavoring to show how they depict the evolution of a single theory. As noted earlier, Ayres' original model was one of sensory integrative *function.* In her model, she illustrated the ways in which the integration of various sensory inputs contributed to different behaviors and performance skills, all in the end resulting in higher level "end products." None of the published models contradicted these original relationships.

We asked each of our interviewees to sketch a model that depicted the way that *they* thought about, or taught, SI theory, and none of those deviated substantially from the relationships that Ayres originally hypothesized. Instead, each of the models expanded one or more aspects of the original model. For instance, most further defined "integration of sensory inputs" to include both sensory discrimination and sensory modulation. Similarly, there was consensus that it is the *sensory discrimination* aspect of integration that supports the development of postural, ocular, or bilateral skills; somatopraxis; and visuopraxis (when this later construct is included). *Sensory modulation* was generally seen to support behavior, attention, and arousal. Our scholars did not always include the end products that Ayres had included, but when they did, they were high-level skills (e.g., academics, abstract thought). Some of the scholars listed praxis as an end product; others included praxis as a more basic product of integration. It is safe to say that all our interviewees would have added end products had we specifically asked.

At the STAR (Sensory Therapies And Research) Institute, Miller and colleagues (2007) developed a model of practice grounded in ASI theory that also includes core constructs from specific sensory-based interventions and other theories or models: caregiver-child interaction, caregiver engagement in therapy, and caregiver coaching and education. As noted earlier, one of the skills Ayres brought to therapy was her ability to help parents better understand children. However, this reframing was not explicit in Ayres' theory, which was focused on the child rather than the family. Keep in mind that Ayres' work appeared during an era ensconced in the medical model; SI theory was somewhat more comprehensive than other theories of the day in that it was closely tied to both evaluation and treatment. However, Ayres died before family-centered care took hold, and she did not formalize her concepts of family-centered intervention.

From a sensory integrative point of view, the STAR Institute model emphasizes arousal regulation, linked, in many of our interviewees' models, with sensory modulation, and focuses on engagement and relationships. The STAR model, then, does not reflect a new "theory" but rather the integration of theoretical models, linking SI with engagement and relationships. More details on the STAR model can be found in the Appendix to this text.

Other models that will be familiar to many practitioners are those developed by Dunn (1999, 2014). Dunn's models focus on sensory modulation, one of the integrative functions. Dunn expanded upon our understanding of the modulation deficits that Ayres had originally identified. Ayres defined **tactile defensiveness, postural/gravitational insecurity,** and **aversiveness to movement.** Dunn, however, examined the interface between behavioral responses and neurological thresholds across sensory systems. Her work expanded our understanding of differences in the ability to modulate responses to sensation, linking this to thresholds for activation within the nervous system. Again, this was not a new theory but rather a perspective on what underlies sensory responsivity. There is more information on Dunn's model in Chapter 10 (Assessing Sensory Integrative Dysfunction without the SIPT), in the discussion of Dunn's tool, the *Sensory Profile 2.*

Since Ayres' death, others have developed interventions drawn in part from SI theory; we have previously referred to many of these and have captured several in Chapter 18 (Complementary Programs for Intervention). By and large, they are sensory-based or regulation-oriented. As with Dunn's model, then, these other

FIGURE 3-6 The Sensory Challenge Protocol, developed by Miller, has been used to examine neural underpinnings of sensory over-responsivity in various populations of children.

interventions have branched from Ayres' conceptualization of sensory modulation, and they do not reflect a new theory. Instead, they may be best viewed as lines of thinking that grew from the core of SI, making SI a theory with multiple expressions. Providing this expanded view on aspects of Ayres' work has moved our understanding forward in some areas. For instance, the neurophysiological correlates of sensory over-responsivity (see Fig. 3-6) have been investigated by several researchers (e.g., Lane, Reynolds, & Thacker, 2010; Mangeot et al., 2001; McIntosh, Miller, Shyu, & Dunn, 1999; Reynolds, Lane, & Gennings, 2009; Schaaf et al, 2010; Schoen, Miller, Brett-Green, & Nielsen, 2009), and added to our understanding of this aspect of sensory integrative dysfunction. More details on this research can be found in Chapter 16 (Advances in Sensory Integration Research: Basic Science Research).

Alongside of this increased knowledge base regarding modulation, some of our interviewees expressed a fear that we had lost praxis: one of the core components of SI theory. Ayres completed the SIPT just before her death, and, as such, the emphasis of the approach had been on praxis. After her death, many researchers and practitioners moved on to focus on modulation and, as mentioned earlier, seemed to leave praxis behind. Interviewees had this to say:

> It would be interesting to see where her research would've gone . . . where would she be now . . . when you look at the different eras . . . there's the era of the visual, more of the visual motor. And with this space visualization and figure ground tests coming out, and then vestibular becomes such a big deal, and then praxis becomes such a big deal, and then sensory modulation or sensory registration becomes a big deal, but it kind of stops there. . . . It feels like we're sort of stuck in that era of sensory modulation being the most important thing where in the past it would be sort of like a 10-year period where a lot of research was done and then we'd move on to the next area, or Jean would move on to the next area.
>
> I think it's not just modulation. You certainly have to deal with modulation, but then also people kind of have the idea [that] you need to deal with the modulation first, before you can deal with the praxis, and don't see it [modulation] as something that just is all the way through.

This emphasis, this focus, had become a point of disagreement for some of our interviewees, potentially because it appeared that "sensory processing" now meant "sensory modulation," which, in turn, is synonymous with SI. With this chain of events, the place of praxis in SI (i.e., the impact of poor integration on the development of praxis) appears to have been lost. Given that Ayres' final contribution to the field was all about praxis, this loss is disturbing. It is possible that the apparent emphasis on sensory modulation was fueled by the growing understanding of sensory modulation dysfunction in children with autism, at a time when the diagnosis of autism was on the rise. We were told:

> So, I think that we were caught in this also because autism started being so prevalent, and in the autism world . . . that was where the money was. The money was in autism and . . . into social and repetitive behaviors, and not so much into praxis.

This same interviewee went on to state: "the evidence itself for the theory is more tipped to modulation or to the social, emotional, repetitive autism than the praxis, and it's not like the praxis is not present in the autism . . . but . . . it's not central in the diagnosis."

Moving Forward

Diversity in thinking is never a bad thing; it has the potential to move things forward, uncover alternative ways to accomplish tasks, and display alternative ways to interpret situations (Zollman, 2010). Zollman explained that, as scientists, we actively seek information that guides us to determine the effectiveness of our methodologies. Zollman argued for "transient diversity" (p. 32), which can be understood as diversity of thought, present for enough time that we carefully and thoughtfully examine our own theories but not so long that it interferes with the development of a unified direction. Diversity in thinking is consistent with the multiple directions and models presented here. The unanswered question is whether this diversity continues to benefit the broader field, or if it is time to work toward unification.

What have we gained from the diversity in models and approaches; how have they moved us forward? Certainly, we have gained a greater understanding of the underpinnings of sensory modulation. And perhaps we have developed greater insight into the effect of specific sensory and motor systems on behavior and development, and gained perspectives on how to use sensation in, and for, intervention. Some therapists might also find a renewed understanding of the nature of family-centered and child-focused intervention. The various models and "branches" have common roots in Ayres' mission to understand links among neurophysiological mechanisms, sensory integrative dysfunction, clinical practice, and occupational engagement and performance. Whether these common roots are enough to work toward unification is itself a question that would fuel debate.

What hurdles will get in the way? Inconsistency in terminology is problematic; it confuses the public; it confuses other professionals; and it confuses our own practitioners. We are unlikely to agree as to whether "SI," "sensory processing," or "sensory integration and processing" is the best descriptor. Nonetheless, our roots are in SI theory, assessment, and intervention as developed by Ayres. Use of the terms *sensory processing* versus *sensory modulation* presents another stumbling point although one, it seems, on which we could come to consensus. Moving our understanding of praxis forward, and developing a deeper understanding of sensory perception and discrimination and their links to praxis, is crucial. It is important to recognize that research funding is increasingly difficult to obtain, and this area of research will be no exception. However, other investigators within and outside of occupational therapy are engaged in research on interventions for motor incoordination; the longer we wait, the less likely SI theory is to be linked with praxis.

There are other considerations as we look to models and their application in practice. Parham and colleagues (2007) identified the core elements of sensory integrative therapy in the ASI Fidelity Measure (Parham et al., 2007, 2011). This tool, based on the fidelity measure developed by Miller, Coll, and Schoen (2007), guides practice and research to maintain "fidelity" to the core principles of ASI. Although some research has been conducted on the effectiveness of the intervention, more needs to be done, and funding will be needed to accomplish this research. Schaaf and Mailloux's (2015) clinical reasoning approach, focused on using assessment findings to guide the choice of goals and defining clear outcomes when using SI in treatment, has merit but has not been thoroughly investigated. In this text we have addressed SI theory as a basis for coaching (Chapter 17, Using Sensory Integration Theory in Coaching) as a tool to enable children to succeed in everyday tasks *despite* sensory integrative dysfunction. Clearly integrating and evaluating the effectiveness of task and environment interventions within models of SI intervention also requires investigation.

HERE'S THE POINT

- New conceptual models and models of intervention have emerged based upon Ayres' work, but they largely align with her original theory.
- Since Ayres' death, much research has emerged in the area of sensory modulation; however, more focused study is needed in the areas of sensory discrimination and praxis.
- Continued research is needed on the effect of interventions that have their roots in SI theory.

Summary and Conclusions

Conducting these interviews shed important light on the history of SI theory and practice. Our colleagues reflected on their understanding of SI along many different paths, and by listening and considering their comments, we came to realize there was a base of positive intent that ran through each perspective. The interviews pointed to more similarities than differences. The stories we heard were heart-warming and heart-wrenching. Only one scholar we wished to include in these interviews refused to talk to us. We gained a better picture of Ayres as a person, a scholar, a researcher, a clinician, a theoretician, and a reluctant leader. We heard remarkably little disparity on how history unfolded. Although relevant scholars were not fully unified in modeling SI, the differences seemed more to reflect different emphases rather than schisms in the theory. Nonetheless, there remains much to do, much to learn, and much to understand as we continue to study and apply SI theory to practice.

Acknowledgments

Although we decided not to identify individual contributions to the information presented in this chapter, we do want to express our sincere thanks to all who we interviewed as we pursued these historical insights. To Erna Blanche, Sharon Cermak, Florence Clark, Dottie Ecker, Diana Henry, Judy Kimball, Sue Knox, Lawrene Kovalenko, Zoe Mailloux, Shay McAtee, Lucy Miller, Shelley Mulligan, Diane Parham, Roseann Schaaf, Sarah Schoen, Susanne Smith Roley, and Pat Wilbarger: We thank you all for your knowledge and wisdom, your willingness to share, and your time in interviews, reviews of transcripts, and review of this chapter. To say the chapter would not have been possible without you is a significant understatement.

Where Can I Find More?

Here you will find some of Ayres' early work. You might enjoy reading this history for yourself!

Ayres, A. J. (1954). Ontogenetic principles in the development of arm and hand functions. *American Journal of Occupational Therapy, 8*(3), 95–121.

Ayres, A. J. (1958). The visual-motor function. *American Journal of Occupational Therapy, 12*(3), 130–138.

Ayres, A. J. (1961). Development of the body scheme in children. *American Journal of Occupational Therapy, 15*(3), 99–102.

Ayres, A. J. (1963). The development of perceptual-motor abilities: A theoretical basis for treatment of dysfunction. *American Journal of Occupational Therapy, 17,* 221–225.

Ayres, A. J. (1964). Tactile functions. Their relation to hyperactive and perceptual motor behavior. *American Journal of Occupational Therapy, 18,* 6–11.

Ayres, A. J. (1965). Patterns of perceptual-motor dysfunction in children: A factor analytic study. *Perceptual and Motor Skills, 20,* 335–368.

Ayres, A. J. (1966a). Interrelation of perception, function, and treatment. *Journal of the American Physical Therapy Association, 46,* 741–744.

Ayres, A. J. (1966b). Interrelationships among perceptual-motor abilities in a group of normal children. *American Journal of Occupational Therapy, 20*(6), 288–292.

Ayres, A. J. (1966c). Interrelationships among perceptual-motor functions in children. *American Journal of Occupational Therapy, 20*(2), 68–71.

Ayres, A. J. (1969a). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities, 2*(3), 160–168.

Ayres, A. J. (1969b). Relation between Gesell developmental quotients and later perceptual-motor performance. *American Journal of Occupational Therapy, 23*(1), 11–17.

Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. *American Journal of Occupational Therapy, 25*(7), 329–334.

Ayres, A. J. (1972a). Basic concepts of occupational therapy for children with perceptual-motor dysfunction. In Proceedings of the Twelfth World Congress of Rehabilitation International, pp. 154–161.

Ayres, A. J. (1972b). Improving academic scores through sensory integration. *Journal of Learning Disabilities, 5*(6), 23–28.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy, 31*(6), 362–366.

Ayres, A. J. (1978). Learning disabilities and the vestibular system. *American Journal of Occupational Therapy, 11*(1), 30–41.

Ayres, A. J., & Mailloux, Z. (1981). Influence of sensory integration procedures on language development (aphasia, apraxia, vestibular disorder). *American Journal of Occupational Therapy, 35*(6), 383–390.

Ayres, A. J., & Tickle, L. S. (1980). Hyper-responsivity to touch and vestibular stimuli

as a predictor of positive response to sensory integration procedures by autistic children. *American Journal of Occupational Therapy, 34*(6), 375–381.

Cermak, S. A., & Ayres, A. J. (1984). Crossing the body midline in learning-disabled and normal children. *American Journal of Occupational Therapy, 38*(1), 35–39.

Sieg, K. W. (1988). *Six perspectives on theory for the practice of occupational therapy.* Salem, MA: Aspen Publishers, Inc.

Here are some additional reads that you might find interesting:

1. Ayres, A. J. (2004). *Love, Jean: Inspiration for families living with dysfunction of sensory integration.* Santa Rosa, CA: Crestport Press.
   A compilation of letters written by Ayres to her nephew, Philip Erwin, that provides unique insights into her thoughts about her research in SI and her own sensory needs.
2. Henderson, A., Llorens, L., Gilfoyle, E., Myers, C., & Prevel, S. (1974). *The development of Sensory Integrative Theory and Practice: A collection of the works of A. Jean Ayres.* Dubuque, IA: Kendall/Hunt Publishing Company.
   A collection of scholarly works written by Ayres that outline the development and refinement of SI theory and practice.
3. Cermak, S. A., Ayres, A. J., Coleman, G., Smith Roley, S., Mailloux, Z., & McAtee, S. (2011). *Ayres dyspraxia monograph, 25th anniversary edition.* Seattle, WA: Amazon Digital Services LLC.
   Original work by Ayres that provides a foundation for understanding the neurobiological basis for praxis and dyspraxia, with additional material provided by current clinicians and scholars.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Ayres, A. J. (1949). An analysis of crafts in the treatment of electroshock patients. *American Journal of Occupational Therapy*, *3*, 195–198.

Ayres, A. J. (1955a). Proprioceptive facilitation elicited through the upper extremities. *American Journal of Occupational Therapy*, *9*(1), 1–9, 50.

Ayres, A. J. (1955b). Proprioceptive facilitation elicited through the upper extremities. *American Journal of Occupational Therapy*, *9*(2), 57–77.

Ayres, A. J. (1955c). Proprioceptive facilitation elicited through the upper extremities. *American Journal of Occupational Therapy*, *9*(3), 121–144.

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Torrance, CA: Western Psychological Services.

Ayres, A. J. (1989). *Sensory Integration and Praxis Test (SIPT) manual*. Torrance, CA: Western Psychological Services.

Ayres, A. J. (2004). *Love, Jean: Inspiration for families living with dysfunction of sensory integration*. Santa Rosa, CA: Crestport Press.

Ballinger, G. A. (2007). Individual reactions to leadership succession in workgroups. *Academy of Management Review*, *32*(1), 118–136.

Dunn, W. (1999). *Sensory Profile*. San Antonio, TX: The Psychological Corporation.

Dunn, W. (2014). *Sensory Profile-2: User's manual*. San Antonio, TX: The Psychological Corporation.

Fisher, A. G., & Murray, E. (1991). Introduction to sensory integration theory. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration theory and practice* (pp. 3–26). Philadelphia, PA: F. A. Davis.

Gorman, M. E., & Kashani, N. (2017). A. Jean Ayres and the development of sensory integration: A case study in the development and fragmentation of a scientific therapy network. *Social Epistemology*, *31*(2), 107–129. doi:10.1080/02691728.2016.1241322

Henderson, A., Llorens, L., Gilfoyle, E., Myers, C., & Prevel, S. (1974). *The development of sensory integration theory and practice*. Dubuque, IA: Kendall/Hunt Publishing Company.

Kielhofner, G. (2004). *Conceptual foundations of occupational therapy*. Philadelphia, PA: F. A. Davis Company.

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience*, *4*(8), 1–14. doi:10.3389/fnint.2010.00008

Mangeot, S. D., Miller, L. J., McIntosh, D. N., McGrath-Clarke, J., Simon, J., Hagerman, R. J., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology*, *43*, 399–406.

May-Benson, T. A., & Koomar, J. A. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy*, *64*, 403–414. doi:10.5014/ajot.2010.09071

McIntosh, D. N., Miller, L. J., Shyu, V., & Dunn, W. (1999). Overview of the Short Sensory Profile (SSP). In W. Dunn (Ed.), *The Sensory Profile:*

Examiner's manual (pp. 59–73). San Antonio, TX: The Psychological Corporation.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy*, *61*(2), 135–140.

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *American Journal of Occupational Therapy*, *61*, 228–238.

Miller, L. J., Lane, S. J., Cermak, S., Anzalone, M., & Osten, E. (2005). Regulatory-sensory processing disorders. In S. I. Greenspan & S. Weider (Eds.), *ICDL diagnostic manual for infancy and early childhood* (pp. 73–112). Bethesda, MD: ICDL.

Northouse, P. A. (2015). *Leadership theory and practice* (7th ed.). Los Angeles, CA: SAGE Publications, Inc.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., . . . Summers, C. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy*, *61*, 216–227.

Parham, L. D., Roley, S. S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a fidelity measure for research on the effectiveness of the Ayres Sensory Integration intervention. *American Journal of Occupational Therapy*, *65*, 133–142. doi:10.5014/ajot.2011.000745

Reynolds, S., Lane, S. J., & Gennings, C. (2009). The moderating role of sensory over-responsivity in HPA activity: A pilot study with children diagnosed with ADHD. *Journal of Attention Disorders*, *13*, 468–478.

Schaaf, R. C., Benevides, T., Blanche, E. I., Brett-Green, B. A., Burke, J. P., Cohn, E. S., . . . Schoen, S. A. (2010). Parasympathetic functions in children with sensory processing disorder. *Frontiers in Integrative Neuroscience*, *4*, 4. doi:10.3389/fnint.2010.00004

Schaaf, R. C., & Mailloux, Z. (2015). *Clinicians guide for implementing Ayres Sensory Integration®*. Bethesda, MD: AOTA Press.

Schaaf, R. C., Schoen, S. A., May-Benson, T. A., Parham, L. D., Lane, S. J., Smith Roley, S., & Mailloux, Z. (2015). The issue is—State of the science: A roadmap for research in sensory integration. *American Journal of Occupational Therapy*, *69*, 6906360010. doi:10.5014/ajot.2015.019539

Schoen, S. A., Miller, L. J., Brett-Green, B. A., & Nielsen, D. M. (2009). Physiological and behavioral differences in sensory processing: A comparison of children with autism spectrum disorder and sensory modulation disorder. *Frontiers in Integrative Neuroscience*, *3*, 1–11. doi:10.3389/neuro.07029.2009

Sieg, K. W. (1988). *Six perspectives on theory for the practice of occupational therapy*. Salem, MA: Aspen Publishers, Inc.

Zero to Three. (2016). *DC: 0–5™ Diagnostic classification of mental health and developmental disorders of infancy and early childhood*. Washington, DC: Author.

Zollman, K. J. S. (2010). The epistemic benefit of transient diversity. *Erkenntnis*, *72*, 17–35. doi:10.1007/s10670-009-9194-6

PART

II

The Neuroscience Basis of Sensory Integration Disorders

CHAPTER

4

Structure and Function of the Sensory Systems

Shelly J. Lane, PhD, OTR/L, FAOTA

. . . the structure/function duality is merely a didactic convenience. In reality, structure allows function and function gives meaning to structure.

—Cohen, 1999, p. 3

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Identify components of the central and peripheral nervous systems.
- ✔ Review the structure and function of the primary sensory systems associated with sensory integration theory.
- ✔ Develop an understanding of links between sensory system structure and sensory integrative function and dysfunction.

Purpose and Scope

Students faced with their first neuroanatomy class commonly feel a sense of foreboding. There is seemingly endless detail within the central nervous system (CNS) and the connecting peripheral nervous system (PNS), and developing a thorough understanding not only of structure and function but also of interrelationships between and among structures and functions seems a daunting undertaking. In this chapter, the learning process is a little less daunting: A small piece of the neuroscience pie is presented, beginning with some basics relative to the central, peripheral, and autonomic nervous systems, and then emphasizing sensory system structure, function, and integration. We will address in most detail the sensory systems most closely aligned with sensory integration (SI) theory, the tactile and proprioceptive (together referred to as **somatosensory**), as well as vestibular, systems. Auditory and visual systems will be covered in somewhat less depth, and the olfactory and gustatory systems will also be presented. A single chapter on only the sensory systems can hardly do justice to these topics; entire books have been written about each. Thus, this should be considered an overview, a review for many readers. For each system, an attempt has been made to provide integrative information that combines structure and function. For more detailed information, readers are referred to the books listed in the reference list and to the other chapters of this book.

Basic Structure and Function of the Central Nervous System

Before diving into the structure and function of the sensory systems, we need to consider where this information fits in SI theory. In Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited), a schematic of sensory integrative dysfunction was presented, and it is reproduced here, adapted to include "interoception" (Fig. 4-1).

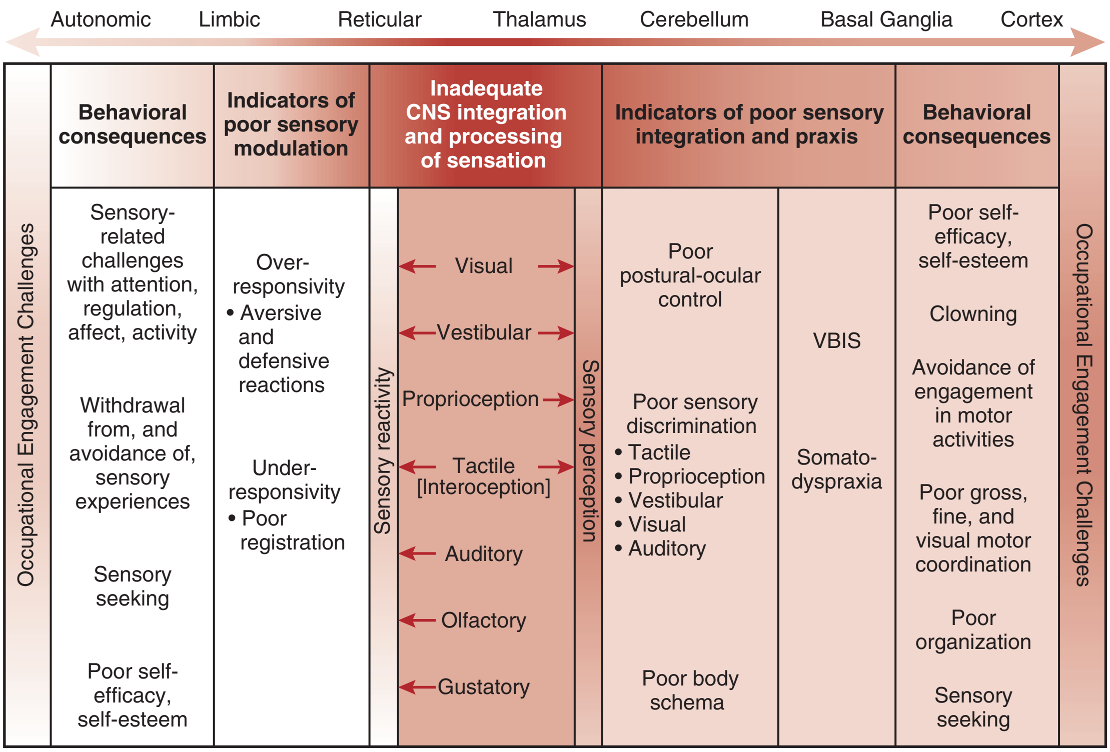

FIGURE 4-1 Complex schematic representation of sensory integrative dysfunction. In this version of the model, we have added interoception as a sensory input.

As previously described, the figure is best understood by first considering the sensory systems, located at the center of the schematic. Understanding the sensory systems is central to understanding SI theory; this is where we begin.

Cells of the Central Nervous System

The basic building block of the nervous system is the neuron. The neuron consists of a cell body, axons, and dendrites (Fig. 4-2). The cell body is the metabolic center of the neuron. Extending from the cell body are two types of processes: axons and dendrites. Typically, there is only one axon, which carries information from the cell body to the target. Although generally only a single axon exits a cell body, it may split into many branches, thereby allowing a single neuron to influence many targets. Axon diameter varies from 0.2 to 20 μm, a feature that will help determine the speed with which information is transmitted; the larger the axons, the more rapid the transmission. Axons may be myelinated or surrounded by a nodular sheath of fatty substance. Myelin offers insulation to the nerve fiber and increases transmission speed along the axon. Axons act similar to cables in a communication network, carrying information within and across regions of the CNS. And, similar to cables, larger axons with more insulation (myelin) transmit information more quickly and with less loss of signal strength than do the small, uninsulated axons (Bear, Connors, & Paradiso, 2015).

Dendrites are responsible for bringing information into the cell body. Dendrites are often extensively branched, allowing communication with many other neurons. The dendritic branches are rich in synapses, allowing for immense communication with other neuronal fibers. This structure is foundational for the integration of inputs, a basic function of the nervous system (Bear et al., 2015). Dendrites and axons combine to form the pathways of the CNS. Fiber bundles and pathways travel varying distances within the CNS and carry information from the CNS to the effector organs and muscles in the body.

Glial cells surround and greatly outnumber neurons. One form of glia, the astrocyte, is shown in Figure 4-3. Glial cells do not have the same

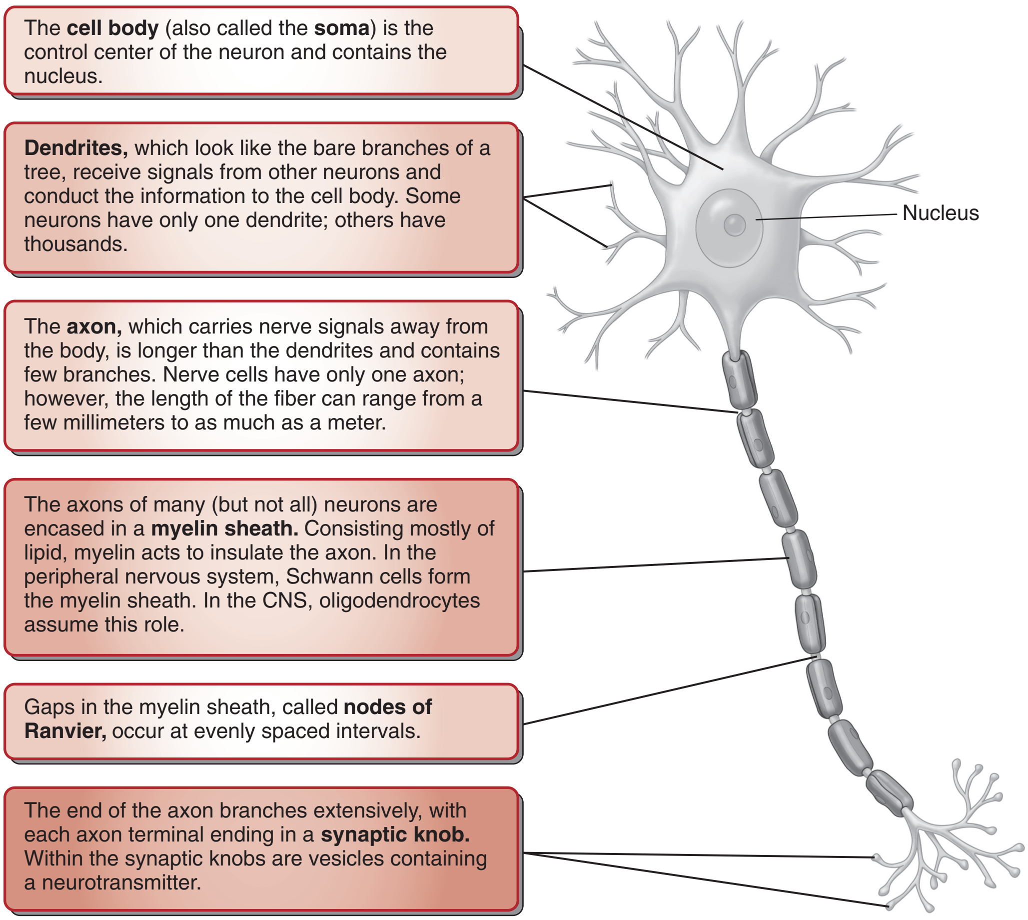

FIGURE 4-2 The neuron, with a myelin sheath around the axon. *From Thompson, G.S. [2013].* Understanding Anatomy and Physiology *[1st ed.]. Philadelphia: F.A. Davis, p. 157, with permission.*

electrical transmission properties of neurons, but instead they:

- Provide structural support to the nervous system.
- Insulate groups of neurons from each other.
- Remove debris after injury or cell death.
- Buffer the electrochemical environment in which neurons exist.
- Nourish neurons.
- Act as stem cells, able to give rise to new glial cells and possibly new neurons.

HERE'S THE POINT

- There are multiple resources to support learning in neuroscience, and they tend to take different approaches to the topic. Readers may need to access more than one resource to develop a thorough understanding of structures and functions in the nervous system.
- The basic building block of the nervous system is the neuron, consisting of a metabolic center (cell body), input (dendrite) and output (axon) fibers.

Central and Peripheral Nervous System Structure

The CNS and PNS are the anatomical divisions of our nervous system; the brain, spinal cord, and meninges form the CNS, whereas the cranial and spinal nerves make up the PNS. There are neuronal cell bodies, axons, and dendrites in both divisions. The nervous system can also be characterized functionally as autonomic (ANS) and somatic. The ANS consists of central

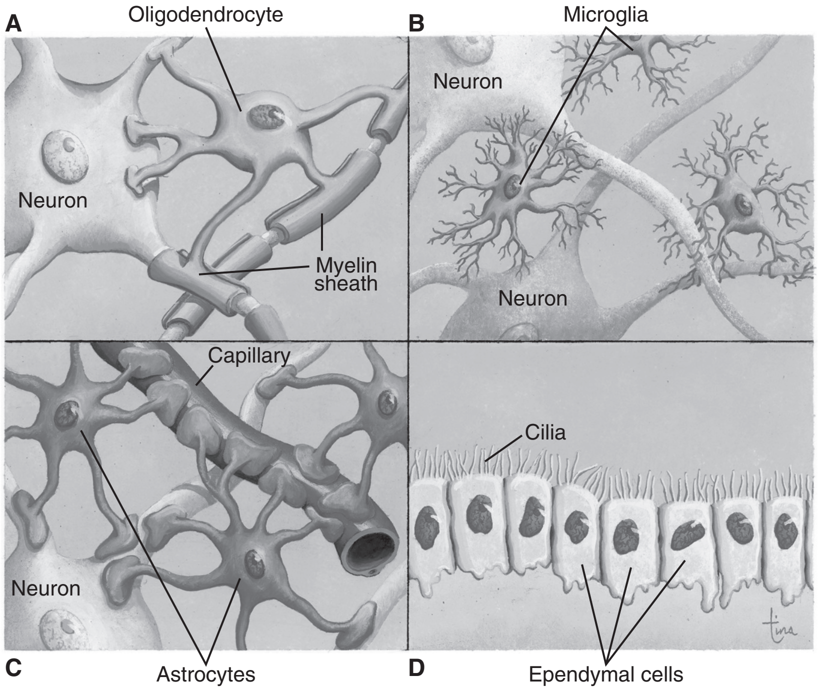

FIGURE 4-3 Glial cells in the CNS take different forms. In A, oligodendrocytes form myelin sheaths around axons. B. Microglia are macrophages, the immune cells of the brain and spinal cord. C. Astrocytes provide metabolic support for neurons and help regulate neural transmission. D. Ependymal cells line the ventricles in the brain and the central canal of the spinal cord, serving as a brain and cerebral spinal fluid interface.

structures and nerve processes that innervate smooth muscle and glands, and the somatic nervous system consists of the components that carry neural signals to or from muscles, joints, and skin (Siegel, Sapru, & Siegel, 2015). These aspects of the nervous system are shown in Figure 4-4. Simplistically, the human nervous system can be likened to a communications network with central hubs and projections transmitting messages into and out of the central core (i.e., the CNS).

Beginning with structural organization, the PNS is composed of receptors, or specialized nerve endings, and the neurons that conduct information to and from the CNS. The PNS then connects the outside world and peripheral structures (e.g., skeletal muscles and glands) to the brain and spinal cord.

Each sensory system has unique and specialized receptor cells or nerve endings that are particularly sensitive to one form of physical energy; for instance, rods and cones in the retina are specialized receptor cells that respond to light energy, whereas the Pacinian corpuscle in the skin is a specialized nerve ending that responds to deep pressure and vibration. Once a receptor responds to a sensory stimulus, a cascade of events takes place that results in transmission of the specific features of that input over afferent fibers to the CNS. Features of sensation that are sent to the CNS include the characteristics such as the intensity of the input, the duration, and, of course, the kind of sensation (Purves et al., 2011). The PNS also has efferent nerve fibers and specialized receptors that transmit the signal from the CNS to effectors. When the effectors are muscle fibers, the receptor is the neuromuscular junction. Effectors may also be visceral structures, innervated by fibers associated with the ANS. Here, too, there will be specialized receptors.

The ANS mediates homeostasis; it regulates such things as blood pressure, heart rate, respiration, and digestion by responding to pressure and stretch in organs and glands, changes in body chemistry, pain, and temperature (Purves et al, 2011; Siegel & Sapru, 2013). The use of the label "autonomic" indicates that this component of

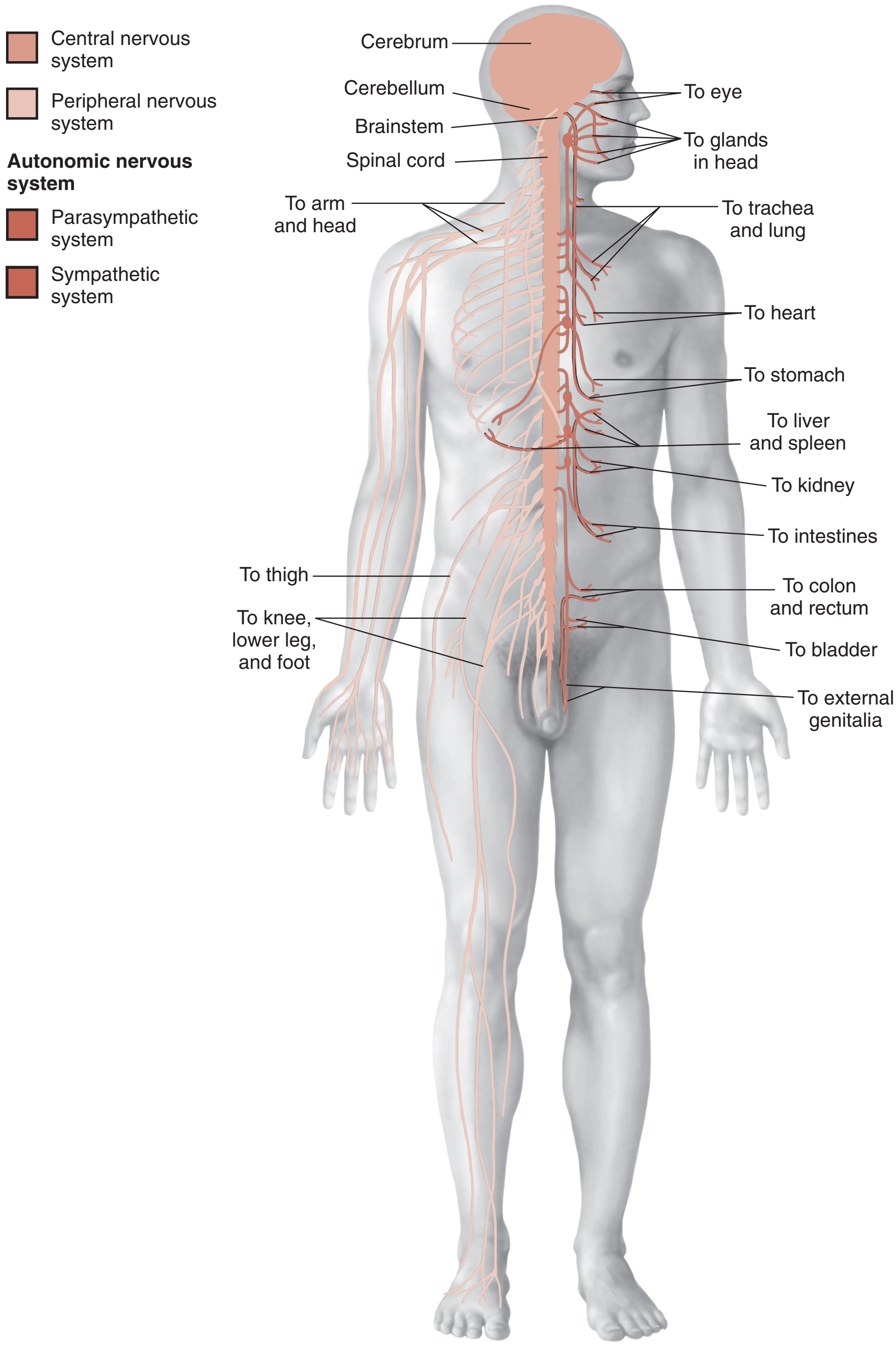

FIGURE 4-4 Central (pink), peripheral (light pink), and autonomic (black and dark pink) nervous system distribution. The ANS is further broken out into parasympathetic (black) and sympathetic (dark pink) components. Note that most internal organs and glands receive both parasympathetic and sympathetic innervation. *From Eagle, S., et al. (2009).* The professional medical assistant. *Philadelphia, PA: F.A. Davis Company: p. 438; with permission.*

the nervous system functions without conscious control in maintaining the body's physiological homeostasis. Information received is transmitted to the CNS through peripheral and cranial nerves. Within the CNS, the hypothalamus, thalamus, and limbic system, along with areas within the medulla and pons, are responsible for mediating autonomic functions. The efferent fibers of this system innervate smooth muscle, cardiac muscle, and glandular epithelium.

The efferent component of the ANS is composed of two major divisions: sympathetic and parasympathetic. The sympathetic division functions to prepare the body for fight or flight; it is most active during periods of stress and serves to increase the body's use of energy. The parasympathetic division has a "rest and digest" function, restoring the energy stores in the body by promoting digestion of food and absorption of nutrients. These two major divisions of the ANS may innervate the same organ and act in concert to continuously regulate activity in that organ. For example, the heart is influenced by both sympathetic and parasympathetic inputs that control functions such as heart rate. Sympathetic activation will increase heart rate whereas parasympathetic activation will decrease heart rate. The systems act in concert to mediate cardiac response to changes in the internal or external environment.

The enteric nervous system is an additional aspect of the ANS that functions in a semi-independent manner (Fig. 4-4) (Purves et al., 2011). This system innervates the gastrointestinal (GI) tract, carrying both sympathetic and parasympathetic information. Interestingly, there are many neurons in the GI system that are not under ANS control, yet they are still part of the enteric nervous system; this is why it is considered "semi-independent." The enteric nervous system monitors and controls chemical and mechanistic aspects of GI function.

We will talk more about interoception, but we will not further address the specifics of ANS structure or function in this text. However, the way in which sensory processing takes place within the nervous system is often interpreted as a reflection of ANS activity. For instance, when a child with tactile defensiveness overreacts to a nudge from a classmate, the sympathetic component of the ANS may have been activated. Similarly, when we suggest the use of deep pressure or heavy work to act as a calming or focusing agent for a child, we are considering the potential ability of this input to increase activity in the parasympathetic division of the ANS. Thus, as you read, consider how the behaviors identified in children or their responses to intervention potentially reflect activity within the ANS. We have pointed out when systems project to components of the ANS.

Central Nervous System Geography

The CNS consists of the brain and the spinal cord. The spinal cord contains both afferent and efferent fibers carrying information to and from the brain and cell bodies located in the PNS. In addition, there are numerous local interneurons (small neurons that reside entirely within the cord) that are responsible for information processing and integration. Using a computer analogy, the spinal cord is roughly equivalent to a large housing through which several cables run from peripherals to the computer tower. However, because processing does occur in the spinal cord, this analogy falls somewhat short.

The brain can be grossly divided into the cerebrum or cerebral hemispheres, diencephalon, cerebellum, and brainstem (Fig. 4-5). The cerebrum includes four lobes with which you are likely familiar (i.e., frontal, parietal, occipital, temporal; see Fig. 4-6) and two others, the limbic lobe or cingulate gyrus (visible on the medial surface of the brain) and the insular lobe (forming the floor of the lateral fissure). The diencephalon is composed of the thalamus, hypothalamus, epithalamus, and subthalamus. The brainstem is made up of the pons, medulla, and midbrain (Fig. 4-5).

The midbrain is also referred to as the **mesencephalon,** a reflection of terminology used in describing embryological brain development. Within the midbrain are the inferior and superior colliculi, associated with the auditory and visual systems, respectively; together they are referred to as the **tectum,** forming a tent over the cerebral aqueduct. As an aside, the superior colliculus (SC) is also considered an important integration center for sensory input because it receives input from multiple sensory systems (McHaffie, Fuentes-Santamaria, Alvarado, Gutierrez-Ospina, & Stein, 2012). Another midbrain region, the periaqueductal gray, surrounds the region of the cerebral

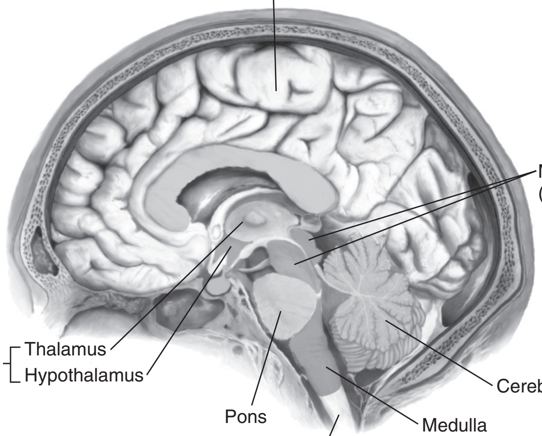

FIGURE 4-5 Two regions of the diencephalon, the thalamus and the hypothalamus, are shown here. *Gylys & Wedding: Medical Terminology Systems, A body systems approach, 6e. F.A. Davis, Philadelphia, with permission.*

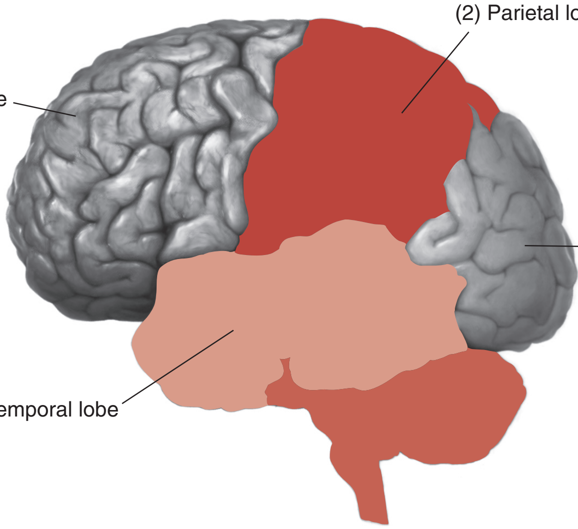

FIGURE 4-6 Lobes of the brain.

aqueduct and thus is located adjacent to the tectum. In the subsequent sections of the chapter, we discuss each of these CNS components as they relate to the sensory systems.

Brodmann areas are also referred to throughout this chapter. Brodmann areas represent a numbering system of brain regions developed by Brodmann in 1909. He thought that each of the 52 numbered regions defined a discrete histological unit within the brain. Subsequent work has shown that only some of these areas have clear functions. However, the numbering that has survived is a useful reference point for identifying cortical regions. Brodmann areas are shown in Figure 4-7.

Central Nervous System Function

Organization of function within the CNS was once thought to be strictly hierarchical, with increasing complexity in the interpretation of input and planning of output as information moved from the spinal cord to the cerebral cortex. According to Squire and colleagues (2012), this hierarchical organization exists and is very apparent in the motor system. In addition, there is a hierarchy in

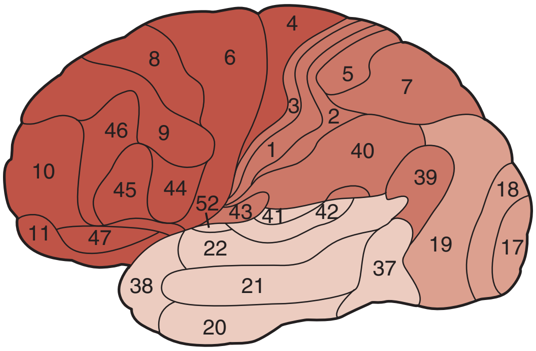

FIGURE 4-7 Brodmann areas on the lateral surface of the brain.

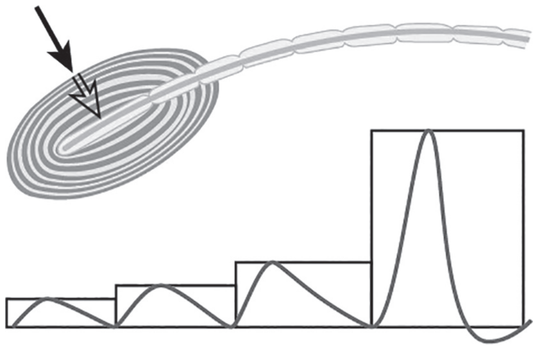

FIGURE 4-8 Receptor potential; local change in ion distribution that, if of sufficient intensity, will transmit information from the receptor toward the CNS. *Reprinted with permission from* Clinical Neuroanatomy, *26th edition, by Stephen Waxman. Copyright McGraw-Hill Education.*

processing sensory input such that at each level within the CNS, greater specificity in interpretation of input is attained. However, the complexity of interactions within and between CNS levels indicates that a heterarchical or network organization also exists. Sensory information reaches all levels within the motor systems, and motor system output is influenced not only by sensory input but also by cognitive processing, other intrinsic activity (e.g., sleep–wake cycles, behavioral state, arousal level, motivation), and sensory feedback from ongoing motor activity. Thus, organization of the CNS is best considered as complex, embracing some aspects of a hierarchy and other interactions more consistent with the intense interaction found in a network of linkages (Squire et al., 2012).

Terminology

Some functional considerations become important as we begin to study the CNS. Because they are all at work in all sensory systems, we define them here and then refer to them within each system as appropriate.

Stimulus Reception and Transduction

Receptors within each system respond optimally to specific types of sensory input. Thus, specific tactile pressure receptors respond best to touch or pressure, and photoreceptors in the eye respond best to light. Although the receptors are different for each system, the process of changing the input from physical to electrochemical has some similarities. Using the tactile system as an example, deep pressure activates a receptor, such as the Pacinian corpuscle. The pressure changes membrane characteristics in the receptor, and this process leads to transduction of the mechanical (pressure) input into an electrical signal. From physiology class, you may recall that all cells have an "electrical potential" established by the distribution of charged ions on the inside and outside of the cell membrane. Activation of the receptor (in this case, touch pressure) leads to changes in the distribution of these ions, which changes the charge distribution across the membrane and results in a local depolarization of the immediately surrounding membrane. The term applied to this local depolarization is a *receptor potential* (Fig. 4-8). At times, when the stimulus is very weak, the electrical charges are minimal and the receptor potentials are not strong enough to lead to transmission beyond this level, so the input is transmitted only a short distance from where it began, similar to a whisper spoken to a large group of people. Those close by may hear it, but unless they pass it on, those on the far side of the group will not, and the message will die a short distance from where it began.

If the stimulus is of sufficient intensity or applied for a long enough period of time, receptor potentials can be added together, and the result is the production of an action potential in the sensory neuron. An action potential is also a change in the distribution of charge on the membrane, but it is strong enough to depolarize neighboring areas on the neuron, and a wave of depolarization is generated that carries the information to its first synapse on the way to the CNS.

Stimulus Encoding

One action potential, in any system, generated by any input is the same as another. How, then, does the CNS discriminate between bright light and firm touch? Discrimination relies on the specificity of receptors for a type of sensory input and requires interpretation within the CNS, based on pathways and connections of the sensory neurons. Receptors convey the information that a touch was firm instead of soft by encoding the stimulus characteristics into a pattern of action potentials that represents intensity, duration, and movement of the stimulus. A stronger stimulus results in an increase in the frequency of action potentials sent to the CNS and is likely to activate more receptors when applied. Thus, strong inputs are read as such in the CNS because they generate more action potentials within one neuron and because the input is detected by multiple receptors so that action potentials are transmitted by a large number of neighboring neurons. This process of specificity in receptors has parallels in computer systems as well. The electrical wires that connect both the keyboard and mouse to your computer are essentially the same; they transmit electrical current in the same manner after the current is generated. The specificity comes from the receptors, in this case the keyboard keys and mouse pad. The keys respond to pressing, and they respond best when we press them in an appropriate sequence, as in spelling a word. The mouse responds to a different input, a dragging touch that moves around the mouse pad. We can change the frequency (hitting a keyboard key multiple times) or influence the "intensity" of the input or word we are typing by doing such things as typing in bold or in all capitals.

Receptor Fields

The term **receptor field** or **receptive field** refers to the area around a receptor from which input can be transduced into an electrical signal (Fig. 4-9). This concept is applied to mechanical receptors of the tactile system where the receptor field is that area of skin surrounding a single receptor, which activates the receptor. In the visual system, the receptor field of a photoreceptor is that area of the retina in which it is found. Small receptor fields are associated with fine discriminative function because they contribute to a precise representation of input at the CNS. Returning to the computer analogy, this is similar to the receptive area available on a standard keyboard compared with the key pad on a smartphone.

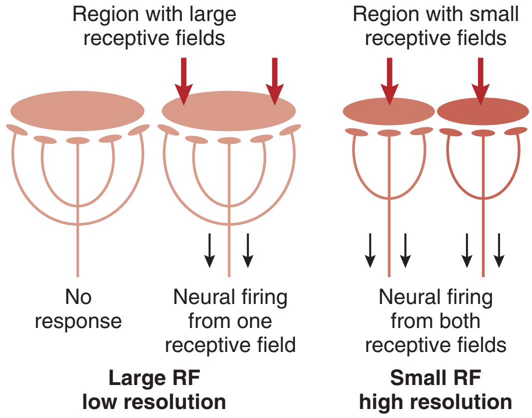

FIGURE 4-9 Large and small receptive fields. Note that with smaller receptive fields the same stimulus (in this image, the two red arrows) activates two neurons, whereas with larger receptive fields only a single neuron is activated. The smaller receptive field transmits more detailed information about what has touched the skin.

Receptor Adaptation

Receptors adapt to continued input, and depolarization of the receptor membrane ceases, even with continued input. Some receptors are considered rapid adapting, responding only at the onset and offset of input. Others are slow adapting, responding in a more continual manner to ongoing input, but eventually even these will cease to produce action potentials. The adaptation of receptors becomes critical in the function of the sensory systems, and this function plays a role in providing ongoing information about what is happening (slow adapting receptors), along with information on changes in the internal or external environment (rapid adapting receptors).

Lateral Inhibition

Lateral inhibition (Fig. 4-10) is another phenomenon that is important to understanding how we receive and interpret neural signals. It is the mechanism used by the CNS to focus input from the receptors and thereby sharpen its interpretation. Lateral inhibition relies on the presence of inhibitory interneurons. It happens like this: a stimulus—for example, a touch—is applied to the hand. Receptors in the skin are activated,

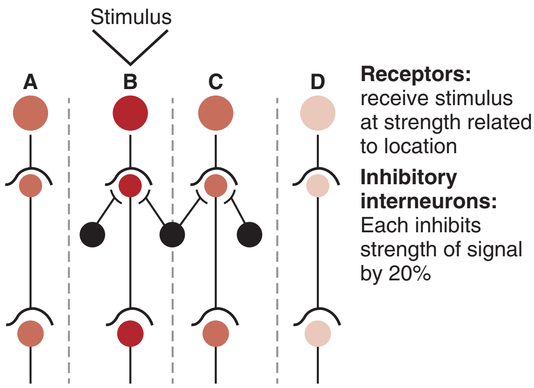

FIGURE 4-10 Schematic of lateral inhibition. In this diagram, the stimulus is applied as shown, and the receptors directly under it will respond with full strength, whereas those located laterally will respond with less strength. Thus, receptor B will respond at 100%, A and C at 80%, and D at 60%. The small inhibitory interneurons reduce the stimulus by 20%. Thus, stimulus strength in each neuron is reduced by 40% at this level, and neurons A and C now transmit at only 40%, B at 60%, and D at 20%. This information transmitted from this point forth then is more focused; little information is transmitted over neuron A and none over neuron D. This process can occur at all synapses along the route of transmission, and it will serve to sharpen the initial input received by the receptor. (The values associated with stimulus strength and interneuron inhibition are arbitrary.)

and those with their receptive fields centered under the stimulus respond with greater strength (more action potentials and more rapid firing). This is analogous to speaking softly to a group of people; those directly in front of the speaker will hear the bulk of the message, but those on the edges will capture less of the information. Fibers from the receptor will synapse with other sensory neurons as they transmit information to the CNS, much as the people in this group talk with their neighbors. In the absence of lateral inhibition, the activation pattern spreads widely, with increasing numbers of sensory neurons activated, and the result at the CNS is some general awareness that a large region of the skin was touched. In the speaking example here, it would be as though each person who heard the message spoke it again to a neighbor, and the neighbor shared it with another neighbor so that soon the whole room would be buzzing with sound. However, the specifics of that sound would be rather vague. Lateral inhibition is used to focus the input rather than allow it to be diffused over many neurons. In sensory systems using this focusing mechanism, the neurons at the center of the receptor field (i.e., those most intensely activated by the input) activate inhibitory interneurons at their first synapse within the CNS. These inhibitory interneurons connect with sensory neurons farther from the center of the receptive field (i.e., less active neurons) and inhibit transmission at the periphery of the receptive field. Other terms used to define this process include **surround inhibition** and **inhibitory surround.** The process is the equivalent of people in the center of a room gently shushing their neighbors to prevent them from speaking. This cuts down on the background noise in the room, making the original message more clearly delivered, at least to the people permitted to hear it. In the CNS, lateral inhibition serves to focus the input at each relay station, reducing background noise. This results in the ability to discriminate and localize the input we receive. Sensory systems with well-developed discriminatory functions rely on this mechanism.

Convergence and Divergence

Convergence and divergence (Fig. 4-11) are concepts that need to be understood in order to appreciate the accuracy with which information is conveyed from the PNS to the CNS. With convergence, many cell processes synapse at one site. Thus, many axons may synapse on the same neuronal cell body or dendrite. When this happens, a great deal of information is condensed. This can be useful for increasing the intensity of the information in the CNS and for promoting integration, but the tradeoff is that the specificity of the original input is decreased, similar to several members of an audience offering input to the speaker in rapid succession. The speaker can listen and integrate the information, but the specifics of where each bit of information came from, exactly what was said and by whom, are likely to be lost.

Divergence, on the other hand, occurs when one process synapses with many different cells in the CNS. Earlier in this chapter, we mentioned that axons can divide and influence many other cells; divergence is such an example. An axon leaves a cell body and subsequently makes contact with cell bodies or dendritic branches in

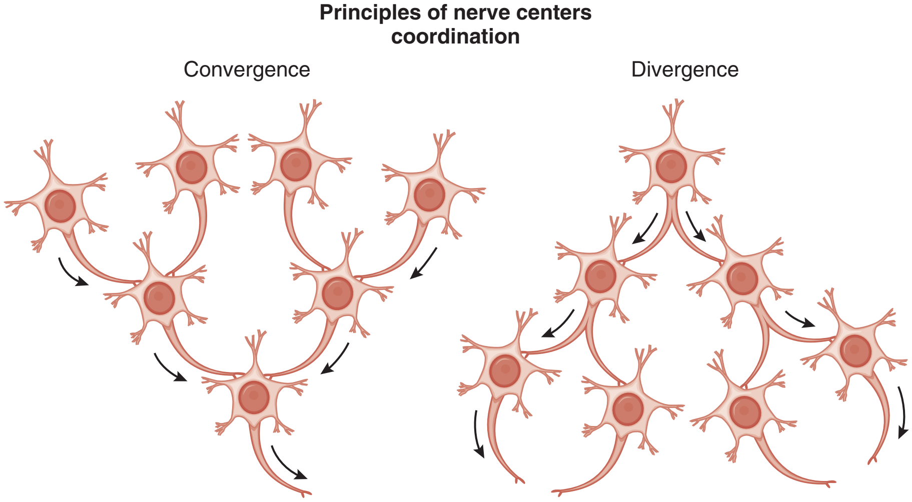

FIGURE 4-11 A schematic depicting convergence and divergence in the CNS.
Reprinted with permission from Lundy-Ekman, L. Neuroscience: Fundamentals for Re-habilitation, *p. 37. Philadelphia, PA: WB Saunders Co., 1998.*

several other areas of the CNS. The functional association here is that the same information is represented at many places, repeated over and over. Thus, the potential impact of this information can be widespread.

Habituation and Sensitization

Our neural networks are highly malleable; changes in synaptic connectivity can be both short or long duration. One of the goals of occupational therapy using SI is to impact neural connectivity through the long term. Two mechanisms have been linked with long-term changes: habituation and sensitization. Behaviorally, you are likely well aware of habituation; you put on clothes in the morning, adjust them to feel comfortable, and then quickly forget about them. This is **habituation,** a process of adapting to sensory input, of becoming less responsive to repeated sensation. **Sensitization** occurs when an aversive response to a specific stimulus is generalized to other, previously non-aversive stimuli. For instance, a child contentedly eats lunch in the school cafeteria until one day when a cart with 20 trays topples, causing a very loud crash and instant chaos. Greatly startled by the combination of the crash and the chaos, the child now pairs these inputs with the cafeteria environment and refuses to go there for lunch. The effect can be either short- or long-lasting, depending on other aspects of CNS processing.

Distributed Processing and Control

The CNS can be masterful in its capacity to "multitask." You read this chapter while you maintain your posture, shift weight to relieve uncomfortable pressure, possibly eat and drink, and digest whatever it is you are drinking or eating. All activities are organized and directed by the CNS. You are engaging sensory and motor systems, cognitive processes, and autonomic functions simultaneously via distributed processing within the CNS. When it works well, distributed processing allows for efficient and effective interactions with the world because the load is distributed among different centers of control.

Serial and Parallel Processing. Underlying distributed control of activities are two processing methods: serial and parallel. In **serial processing,** things occur in sequence, one after another, in a hierarchical manner. Transmitting information from a touch receptor to the CNS occurs this way as the information is mechanically received, transduced into an electrical signal, summed to form an action potential, and transmitted to the CNS. **Parallel processing** involves the work of more than one pathway working simultaneously. Visual, vestibular, and proprioceptive systems often use parallel processing to orient us to our position in space. Each system processes different bits of information about our bodies and the space around us with the integrated endpoint being maintenance of upright posture.

Parallel processing is a term also used when the same sensation is carried and processed in two pathways that have some redundancy. For instance, pain input is processed via both the dorsal column medial lemniscal (DCML) and the spinothalamic pathways. This functional overlap can be very useful in the face of disease or dysfunction that interrupts the flow of information in one system. The fact that the same information can be processed in a parallel system can be capitalized upon in intervention.

There are other processes and mechanisms that could be discussed in this background section, but the ones offered here provide a very basic anatomic and functional baseline. We now focus on the individual sensory systems and integration among sensory systems as a basis for understanding their contributions to SI and occupational performance.

PRACTICE WISDOM

Why do we care about things such as receptor types, receptive field, speed of transmission, and neuronal functions such as lateral inhibition, as well as processes such as divergence, convergence, and habituation? Understanding these functions helps us understand what we are doing clinically when we make sensory experiences available to the children we treat. For instance, if a child brushes lightly against a fuzzy surface and this triggers a defensive or withdrawal response, we likely have triggered a hair cell receptor. We know that these receptors are connected to small neural fibers, and the information will travel to the CNS relatively slowly. When we use firm pressure to rub the spot where the fuzzy surface touched, we are activating deeper receptors, such as the Merkel disc or Pacinian corpuscle. These receptors are connected to larger diameter fibers that are myelinated. This information travels faster to the CNS, and we can use it in effect to diminish the effect of light touch on orienting and arousal. So even though you might not be thinking about receptor types and speed of transmission, you are likely using these constructs clinically and in everyday life.

HERE'S THE POINT

- The nervous system can be conceptualized as consisting of anatomic divisions (CNS and PNS) or functional divisions (ANS and somatic). Together these approaches provide insight into structure and function.
- The PNS connects our periphery and environment to the CNS, bringing sensory input to the brain (afferent input) and carrying central commands away from the brain to the muscles and organs (efferent output).
- Similar to the PNS, the ANS has afferent and efferent components; these components mediate physiological homeostasis.
- The enteric nervous system functions in a semi-independent way to mediate functions of the gut.
- Organization of the CNS, comprising the brain and spinal cord, is best considered a complex interaction of hierarchical and heterarchical structure and function configurations.
- Knowledge of common neuroscience-related terminology supports an understanding of structure, function, and dysfunction in the nervous system.

The Somatosensory System

We begin our discussion of the somatosensory system by reviewing the receptors associated with somatosensation. After being gathered by the receptors, somatosensory inputs are processed over the DCML pathway, spinocerebellar pathways, and the pathways of the anterolateral system (AL). We present each separately. We also discuss the trigeminothalamic pathway, which is responsible for the transmission of somatosensory information from the face. A brief description of the functional overlap between the somatosensory pathways completes this section.

Receptors and Transduction

The majority of receptors in the somatosensory system are mechanoreceptors. This means that when a mechanical force (e.g., light touch, deep pressure, stretch, or vibration) is applied to the receptors, the process of neural transmission begins. Proprioceptive input from joints and

TABLE 4-1 Locations, Modalities of Sensation, Adaptation Rates, and Fiber Types Associated with Skin Receptors

TYPE	LOCATION	STIMULUS	FIBER TYPE	ADAPTATION
Free nerve ending	Dermis, joint capsules, tendons, ligaments	Pain, temperature	A-delta, C	Slow
Hair follicle plexus	Deep dermis	Hair displacement; pain	A-beta	Fast
Meissner corpuscles (tactile corpuscles)	Papillae of skin, mucous membranes of tongue tip	Touch	A-beta	Fast
Pacinian corpuscles	Subcutaneous tissue	Pressure, vibration	A-beta	Fast
Krause end bulb	Papillae of hairless skin; near hair follicle plexus	Cold	A-delta, C	Below 20°C; no adaptation
Merkel disc	Epidermis of hairless skin; hair follicles	Deformation of skin	A-beta	Slow
Ruffini ending	Joint capsules; connective tissue	Touch; skin stretch; joint movement	A-beta	Slow

muscles is certainly a mechanical input, and proprioceptive input is carried along somatosensory pathways. Although we discuss proprioception briefly here, readers will also find proprioception covered in conjunction with the vestibular system in other chapters of this book. The tactile system also includes thermoreceptors and is thus responsible for the interpretation of temperature input. Table 4-1 lists the receptors within this system and their various characteristics.

Tactile Mechanoreceptors

Mechanoreceptors within the skin subserve different types of sensory activation. Some respond to the initiation and cessation of input (Meissner corpuscle, Pacinian corpuscle, some hair follicles) but not to sustained input. These receptors are considered fast adapting because they stop responding to maintained stimuli. They are sensitive to changes in tactile input. Slowly adapting receptors include Merkel discs, Ruffini endings, and some hair follicle receptors. In contrast to the fast-adapting receptors, this second group of receptors provides the CNS with information regarding the intensity, duration, and speed of input (Fig. 4-12).

Our tactile discrimination ability depends, in part, on the density of receptors and the associated size of the receptor field. In areas of fine tactile discrimination (e.g., fingertips, palms, around the mouth), receptor density is high and the receptor field is small. Areas of high receptor density are more skilled. However, in areas where less specific information is needed about tactile input (e.g., abdomen and back), receptor density is low and receptor fields are larger. Researchers (e.g., Jones & Smith, 2014) examining discrimination abilities have shown that, although some things can be distinguished using either active or passive touch, the use of active touch allows finer and more accurate discrimination. The tactile system also capitalizes on lateral inhibition to focus input and refine discrimination.

The somatosensory system, which carries information from the body to the CNS, has two main subdivisions: the DCML system and the AL pathways; there are also crucial projections of proprioception to the cerebellum. The pathways will be described later in this section. Together, the information received by receptors and transmitted over these pathways provides us with the ability to interpret our tactile world and respond appropriately to touch. Because of the pervasive nature of these two somatosensory subdivisions, they are critical to our interactions with the world. Likewise, the pervasive nature of the somatosensory system means that when problems exist, the impact can be widespread.

Proprioception and Proprioceptors

Sherrington (1906) defined **proprioception** as perception of joint and body movements as well as position of the body, or body segments, in space; this definition is consistent with what we read

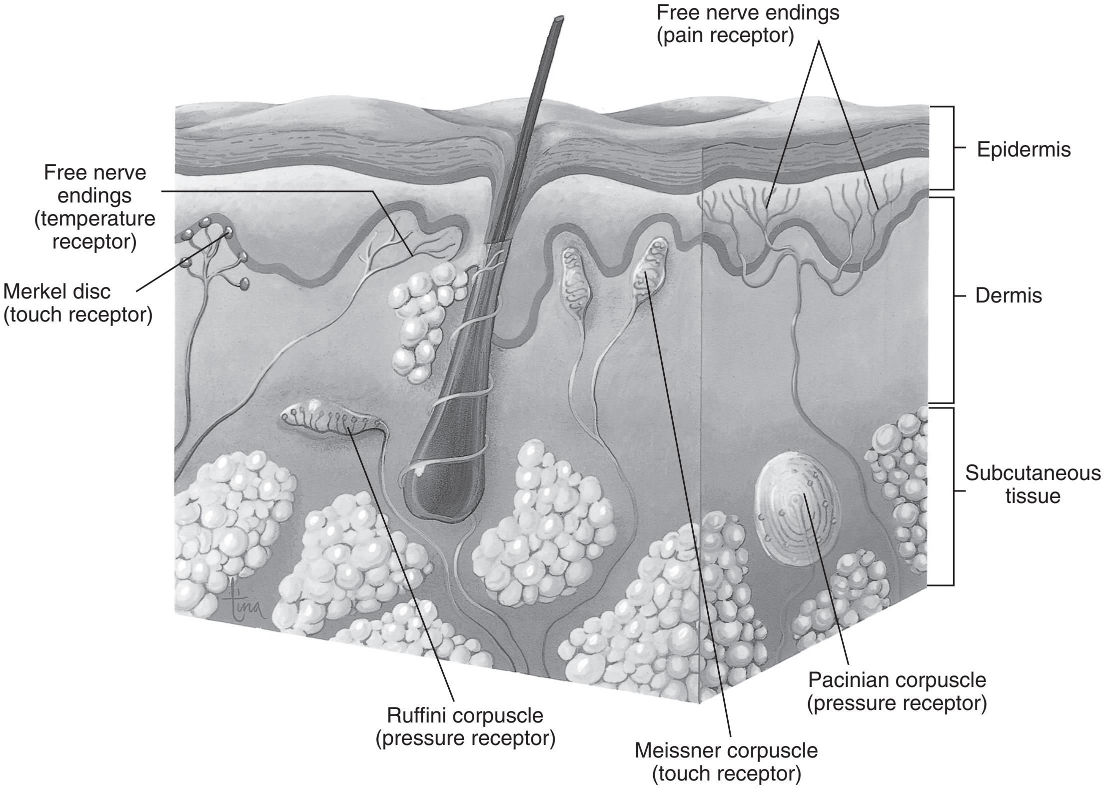

FIGURE 4-12 Skin touch receptors include free nerve endings (dermis and superficial epidermis), Merkel disc and Meissner corpuscle (dermis), and Ruffini ending or corpuscle and Pacinian corpuscle (subcutaneous tissue).

today in the literature (e.g., Croker, 2013; Proske & Gandevia, 2012) and most neuroscience texts (Bear et al., 2015; Purves et al., 2011; Siegel, Sapru, & Siegel, 2015). Proprioceptors provide a continuous flow of sensation from muscles, joints, and tendons, and they inform us about the spatial orientation of the body or body parts, the rate and timing of movements, the amount of force our muscles are exerting, and how much and how fast a muscle is being stretched (Proske & Gandevia, 2012). The continuous flow of information is essential; imagine how it would be to have only intermittent information about your limb and body position in and movement through space. Although Sherrington (1906) and others identified muscle afferents, joint receptors, and the vestibular labyrinth as proprioceptors, we will confine the discussion in this section to the non-vestibular proprioceptors.

Before the early 1970s, researchers distinguished between *conscious* joint proprioception (kinesthesia), thought to arise primarily from joint receptors, and *unconscious* proprioception, thought to arise from the muscle spindle and tendon receptors. However, this distinction is not clearly made, and older experimental evidence indicates that all proprioceptive inputs can contribute to conscious proprioception (Matthews, 1988; McCloskey, 1985; McCloskey, Cross, Honner, & Potter, 1983; Moberg, 1983; Tracey, 1985).

For purposes of studying SI theory, it is more important to understand the distinction between proprioceptors (i.e., proprioceptive receptors) and proprioception (i.e., proprioceptive feedback and perception of joint and body movement). Not all proprioception is derived from peripheral proprioceptive receptors. Internal correlates of the motor signals that are sent to the muscles after an action is planned are also an important source of proprioception; the process is termed **corollary.** Corollary discharge happens when the plan for movement is sent to the cerebellum; the cerebellum "previews" the plan, and it makes some updates based on current information it receives from the muscles and joints. It helps us to finesse our motor actions. Corollary discharge is important for differentiating between active (internally generated) and passive movement (generated by an external stimulus), identifying if we have programmed an appropriate level of motor activity, the development of body scheme, and perception of force (Crapse & Sommer, 2008). Knowledge of the body and its movements is important in motor planning and is also addressed in Chapter 5 (Praxis and Dyspraxia).

Sources of Proprioceptive Input. Proprioceptive feedback arises from several sources. **Muscle spindles,** located in the muscle and running parallel to muscle fibers (Fig. 4-13), are the primary source of proprioception, providing input relative to joint position and movement through the midrange of movement. Proske and Gandevia (2012) indicated that there is indirect evidence for a contribution from **Golgi tendon organs (GTO)** relative to weight and force. The GTO is located in the muscle tendon. Proprioception from joint receptors is minimal and primarily at the end range of movement (Proske & Gandevia, 2012), serving primarily as limit detectors (Ferrell & Smith, 1988).

Looking more closely at how the muscle spindle functions, the effective stimulus for the primary and secondary endings of this receptor is stretch. Primary fibers transmit information regarding the velocity of change in muscle length, as well as amount of change, and secondary fibers transmit information on static positions and sustained stretch and contraction. Both types of fibers are critical for ongoing information about the location of the body and limbs in space.

Information about muscle stretch travels to the spinal cord, where the sensory input connects with ascending fiber pathways (discussed later) and locally with the alpha motor neuron of the same muscle. Alpha motor neurons are efferent fibers coming from the spinal cord and going to muscle fibers to produce muscle contraction. One alpha motor neuron may connect with several muscle fibers; the name for the alpha motor neuron and all the muscle fibers to which it connects is a **motor unit.** Stretch of the muscle activates the muscle spindle, which, in turn, activates the alpha motor neuron, leading to muscle contraction. Muscle contraction leads to increased muscle tension and activation of the GTO, a tension-sensitive receptor.

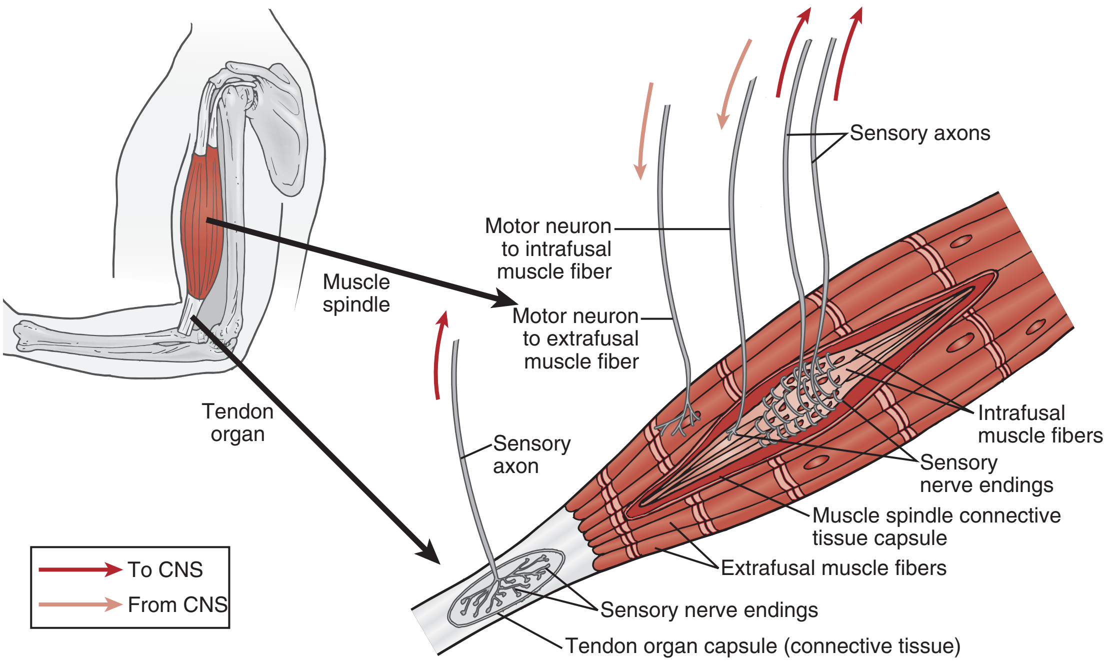

FIGURE 4-13 The muscle spindle with afferent (sensory) fibers carrying proprioception to the CNS, and efferent (motor) fibers to muscle (extrafusal fiber) and muscle spindle (intrafusal fiber). In the tendon there is the Golgi tendon organ, responding to muscle tension.

Stretching or contracting a muscle a little bit results in a little bit of proprioceptive input; working against resistance recruits motor units, providing more information to the CNS about body and limb position in and movement through space (Schmidt & Lee, 2011). This is a concept we can use clinically. For example, when we extend the head and upper trunk against gravity from the prone-lying position, extend weight-bearing limbs to jump on a trampoline, or flex our arms while swinging on a suspended trapeze, we are contracting against the resistance of gravity and body weight. In contracting against resistance, we recruit motor units to produce the needed force for the activity. Therefore, evincing an adaptive behavior against resistance may be the most effective means available for generating proprioceptive feedback.

Stimulation of cutaneous or skin mechanoreceptors and joint receptors by active joint movement is believed to be particularly important in the perception of movement in some, but not all, body areas. For instance, loss of cutaneous input during movement of the knee has not been shown to impair the ability to determine joint position (see Gokeler et al., 2011 for review), and loss of one source of proprioception can be compensated for by input from other receptors (Bear et al., 2015).

Although tactile and proprioceptive information travel in the same pathway (see the text that follows), it is important not to confuse cutaneous-generated proprioception with tactile sensation. *Proprioception* refers to sensations of movement or position that arise because of an individual's own movement. **Tactile sensation** pertains to awareness or perception of the location, or change in position, of an external stimulus applied to the skin. Tactile sensation provides an individual with information about the external environment acting on the skin and skin receptors. Often, tactile information is gathered from movement of joints; this can be a bit confusing. However, by definition, inputs such as deep touch pressure and passive joint compression are not sources of proprioception.

As an example, consider a child swinging on a swing. Proprioceptors are activated by body movements such as holding onto the swing, pumping with the legs, and leaning forward and back with the trunk. Touch receptors are activated in the hand as it feels the rope handles as well as on the head and body as air flows around the movement and the child's hair moves from one direction to the next. Both sources of input provide information about position in and movement through space. The vestibular system plays a role here as well, something that we will come back to soon.

Centrally generated motor commands and efference copy are also sources of proprioceptive feedback. They are thought to be responsible for the sense of effort or conscious awareness that proprioception is happening (Schmidt & Lee, 2011). According to the classic work of McCloskey (1985)

> We have all experienced the sensation of increasing heaviness of a suitcase which we carry with progressively fatiguing muscles. Ultimately, we put down such a load and rest when it has "become too heavy." But the load has not really become heavier: the pressure and tensions in the supporting limbs have not increased, and there is no reason to assume that the discharges from sensory receptors signaling pressures or tensions will have increased either. What makes the load seem heavier is that one perceives the greater effort, the greater efferent barrage of voluntarily-generated command signals, which has been necessary to maintain a contraction with progressively fatiguing and so less responsive muscles. Similar sensations of heaviness or increased muscular force accompany all other states of muscular weakness whether caused experimentally . . . or by disease. (p. 152)

Centrally-generated motor commands and efference copy from motor centers are speculated to be necessary for accurate interpretation of sensation (Schmidt & Lee, 2011). Centrally-generated motor commands and efference copy are also important in motor control, that is, in the planning and producing of an adaptive motor behavior. We present more information on these concepts in Chapter 5 (Praxis and Dyspraxia).

Dorsal Column Medial Lemniscal (DCML) Pathway

Receptors associated with the DCML respond to mechanical stimuli, transmitting primarily tactile, vibratory, touch-pressure, and proprioceptive information. The DCML is associated with functions inherent to tactile discrimination or perception: detection of size, form, contour, texture, and movement across the skin. Because it carries proprioceptive information, the DCML also transmits information relative to the position of the body and limbs in space.

Inputs are transduced into a set of action potentials and transmitted over the axon to the cell body, which, in this case, is in the dorsal root ganglion. There is no synapse here, and the information is passed from the dorsal root ganglion cell body to dendrites that enter the spinal cord and travel to the brain via the dorsal columns of the spinal cord. The DCML is shown in Figure 4-14. The first synapse of the DCML is in the medulla, in the gracile and cuneate nuclei.

From the medulla, fiber tracks cross and form the medial lemniscal fibers, traveling through the brainstem reticular formation and ascending to the ventral posterior lateral (VPL) nucleus of the thalamus. The fact that fiber tracks cross in the brain rather than in the spinal cord has functional implications in the face of an injury or dysfunction. If there is a problem with this pathway at or above the medulla, the functional loss will be on the opposite side of the body. If there is a problem within this pathway below the medulla, it will be reflected on the same side of the body.

Fibers enter the thalamus, synapse, and then send third-order neurons to the cortex. Cortical reception areas for the DCML include the primary and secondary somatic sensory cortex (S-I and S-II, respectively; Fig. 4-15), as well as Brodmann areas 5 and 7 of the posterior parietal lobe, the somatosensory association cortex (Figs. 4-7 and 4-15). The processing up to this point has been an example of hierarchical processing, with more refined information processed at each level. Within the cortex, the hierarchy is less obvious.

In S-I, the somatosensory receptor density and location are precisely represented in a somewhat distorted image of the body known as the **sensory homunculus** (Fig. 4-15). Interestingly, it has been shown that this representation of the body at the cortical level is flexible. Classic research has shown that areas representing specific body parts can be increased in size with intense use, and, likewise, representation is decreased with disuse and concomitant diminished skill (Coq & Xerri, 1999; Jenkins, Merzenich, Ochs, Allard, & Guic-Robles, 1990; Mogliner et al., 1993; Recanzone, Merzenich, & Jenkins, 1992). These findings are important to occupational therapy intervention in general and sensory integrative intervention specifically.

Processing throughout the DCML promotes its discriminative functions. The somatotopic organization of the fibers is precise, with fibers from the leg and foot taking a medial position. As fibers representing the upper leg, trunk, and upper extremity enter the cord, they are added to the pathway laterally. The relationship of the fibers to each other is maintained with high integrity as they travel through the CNS. The somatotopic organization of the fiber pathways is also maintained in the medullary nuclei and in the pathway as it ascends. However, the pathway twists as it approaches the thalamus so that fibers from the arm come to lie medial to those from the leg.

Precise somatotopic organization is only one reason that information in the DCML is transmitted with great accuracy. Other reasons include:

- A minimal number of relays where the signal must be processed
- Little convergence of input en route to the CNS
- Heavy reliance on lateral inhibition to maintain the integrity of a stimulus from the periphery to the CNS

These features allow the brain to interpret the temporal and spatial aspects of DCML inputs, yielding a great deal of information about the location and type of somatosensory information received (Abraira & Ginty, 2013; Bear et al., 2015).

Interpreting Somatosensory Input

Although we generally consider interpretation of sensation to be a function of the cortex, or at least higher levels of the CNS, some processing begins within the gracile and cuneate nuclei in the medulla for the DCML. In addition to somatosensation, these nuclei receive input from the primary sensory cortex and the reticular formation. This convergence of input means that activity in the primary sensory cortex, as well as the reticular formation, influences the interpretation of tactile input, even before it reaches a cortical level.

Thalamic interpretation of DCML inputs is thought to permit vague conscious discrimination of tactile input. There exist inhibitory

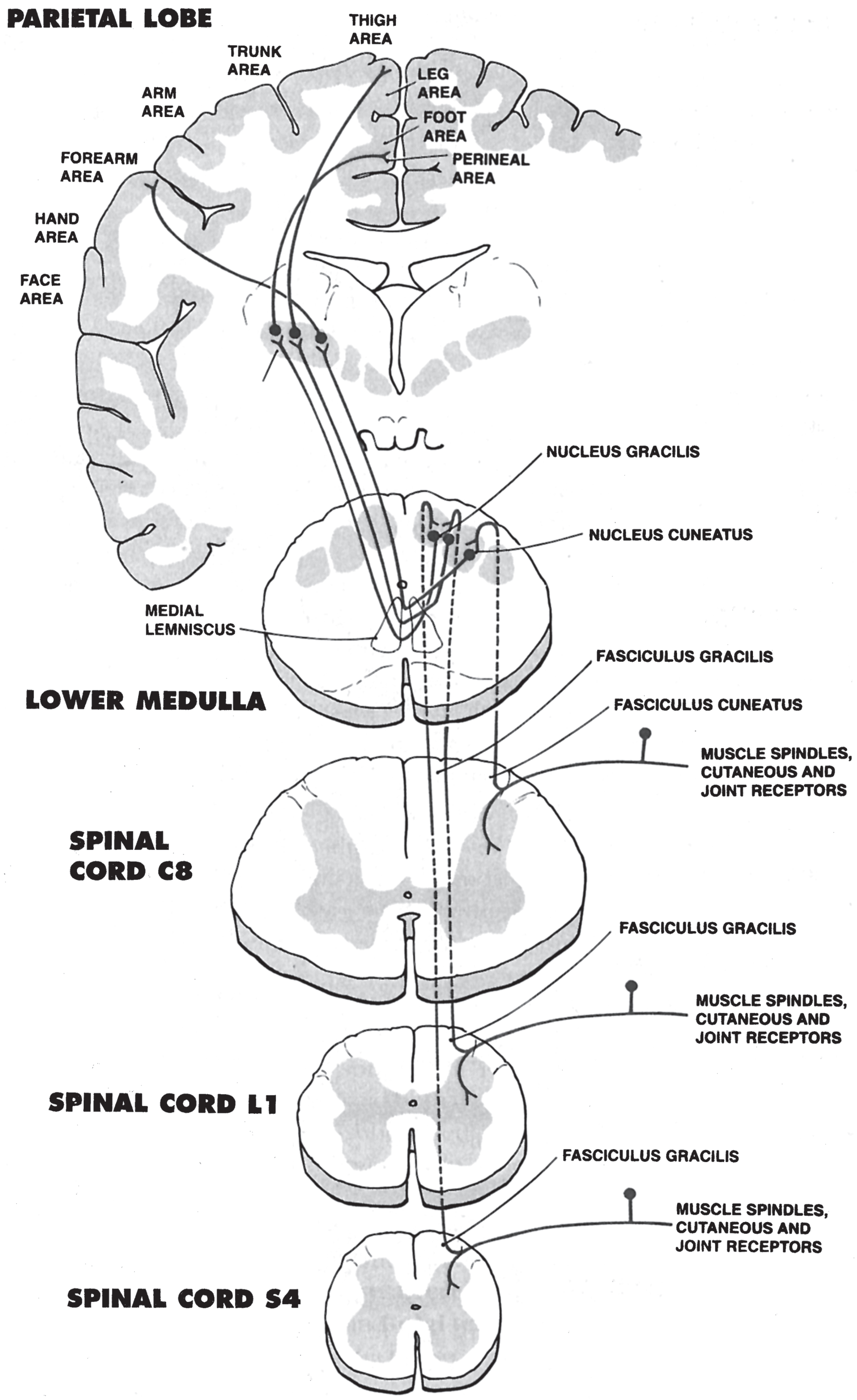

FIGURE 4-14 Dorsal column medial lemniscal system. Note that the information transmitted over this pathway comes from muscle spindles, skin, and joint receptors. That from the lower extremity is transmitted to the *nucleus gracilis* and that from the upper extremity to the *nucleus cuneatus. Reprinted with permission from Gilman, S., and Newman, S. W.* Essentials of Clinical Neuroanatomy and Neurophysiology, *9th edition, p. 62. Philadelphia, PA: F.A. Davis Co., 1996.*

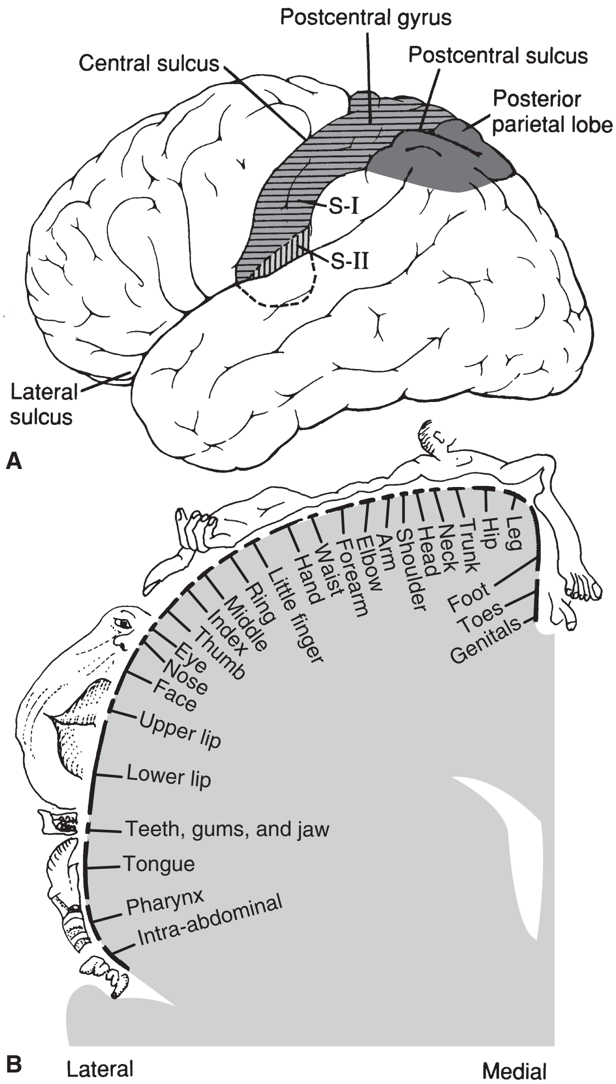

FIGURE 4-15 The primary sensory cortex (S-I) and secondary sensory cortex (S-II) are shown in figure A. Within S-I is the sensory homunculus (figure B). *From Kandel, ER, and Jessell, TM: Touch. In Kandel, ER, Schwartz, JH and Jessel, TM:* Principles of Neural Science, *ed 3. Appleton and Lange, Norwalk, CT, 1991 with permission, pp 368 [A] and 372 [B].*

interneurons in the VPL that are activated by fibers from the cortex as well as inhibited by fibers from other thalamic nuclei. Cortical activation of inhibitory interneurons interferes with further transmission of DCML inputs beyond the thalamus. On the other hand, if the inhibitory interneurons are themselves inhibited by other thalamic projections, information can be processed and sent onto cortical areas. Thus, there is some processing at this level that influences transmission beyond the thalamus.

The primary somatosensory cortex (S-I, Brodmann areas 3, 1, and 2; Figs. 4-7 and 4-15) is subdivided into different processing areas associated with differing types of sensation. Area 3a receives a great deal of input from the thalamus but primarily related to body position in space as opposed to touch. Area 3b is considered to be the primary somatosensory processing region because neurons here respond only to somatosensation (touch and proprioception) (Bear et al., 2015). Considerable somatosensory information passes through 3b before going to areas 1 and 2. Projections to area 2, from area 3b, relate to size and shape. Area 2 also receives significant amounts of information from muscle spindles and GTOs, giving it an important role in proprioception and kinesthesia. Loss of texture discrimination has been associated with damage to area 1, and loss of stereognosis has been associated with damage to area 2. Area 3b has been associated with losses of both of these functional skills, as 3b processes information before passing it on to the areas 1 and 2. This means that areas 1 and 2 likely elaborate sensory input and are, therefore, associated with higher level interpretation of information.

The secondary sensory cortex (S-II, Brodmann area 43; Figs. 4-7 and 4-15) receives input from the VPL as well as from S-I. However, without a functioning primary sensory cortex, neurons within the secondary cortex do not fire. Thus, the secondary cortex depends on the primary cortex for input. Within the S-II, new sensory discriminations are thought to take place. Projections from the secondary cortex to the insular lobe are believed to be involved in tactile memory (Purves et al., 2011).

Further interpretation of somatosensory inputs takes place in the somatosensory association cortex, areas 5 and 7 of the parietal lobe (Figs. 4-7 and 4-15). These regions not only receive input from the thalamus but also from S-I and S-II, and they are connected bilaterally. Some images show these areas to be part of S-II in that they are projection areas from the primary sensory cortex. Both of these parietal regions play sensory integrating roles: area 5 for touch and proprioception, and area 7 for somatosensory and visual inputs. Such processing of inputs from multiple sources makes this a good example of heterarchical organization within the CNS. Because of these connections, lesions in areas 5 and 7 result in deficits in spatial perception, visual-motor integration, and directed attention. Both areas are also associated with the manipulation of objects and are important in discerning their tactile qualities (i.e., haptic perception). Any clinician who has tried to evaluate stereognosis in children who do not automatically manipulate objects can appreciate the importance of manipulation for tactile perception. Lesions in these areas within the right hemisphere have been associated with agnosia of the contralateral side of the body and body space. Tactile sensation is not impaired, but individuals fail to recognize and attend to this side of the body and the environment around it.

Also, within the parietal lobe, aspects of tactile and proprioceptive input converge and subsequently project to anterior motor planning areas of the brain. Thus, output from the DCML could be expected to have an impact on both object manipulation and motor planning. In fact, when outputs from area 2 (a subregion of S-I) to the primary motor cortex are disrupted, hand use becomes uncoordinated. A decrease in sensory feedback to the motor cortex that occurs secondary to interruption of the DCML interferes with the production of coordinated fine motor acts.

Proprioceptive input has been linked with arousal (Rose, Ahmad, Thaller, & Zoghbi, 2009), and inputs from the DCML may have a role in arousal modulation. Clinically, certain types of sensory information have been observed to have a calming effect clinically. Deep touch pressure and proprioceptive information have been theorized, and shown by some, to have this quality (Ayres, 1972; Chen, Yang, Chi, & Chen, 2013; Edelson, Edelson, Kerr, & Grandin, 1999; Reynolds, Lane, & Mullen, 2015; Vasa et al., 2014); both are carried to the CNS via the dorsal columns.

Clinicians and researchers have indicated that poor tactile perception may be related to difficulties in manipulative hand skills (Goodwin & Wheat, 2004; Haron & Henderson, 1985; Johansson & Flanagan, 2009; Yu, Hinojosa, Howe, & Voelbel, 2012). Furthermore, difficulty in perceiving the size and form of an object during the process of active manipulation results in difficulty handling the object. We may also speculate that difficulty in perceiving the boundaries of the hand and the relationship of the fingers to one another interferes with manipulation skills.

Spinocerebellar Pathways

Crucial as a foundation for movement and tone, proprioceptive inputs are also projected to the cerebellum (Fig. 4-16). The cerebellum uses this input, along with vestibular input, to monitor body and limb position in and movement through space, and to regulate the timing of movement. Spinocerebellar inputs form the dorsal spinocerebellar pathway, carrying proprioceptive input from the lower part of the body, and the cuneocerebellar pathway, carrying proprioceptive input from the upper extremities. In addition, proprioceptive information from the face is relayed to the cerebellum from the trigeminal mesencephalic nucleus.

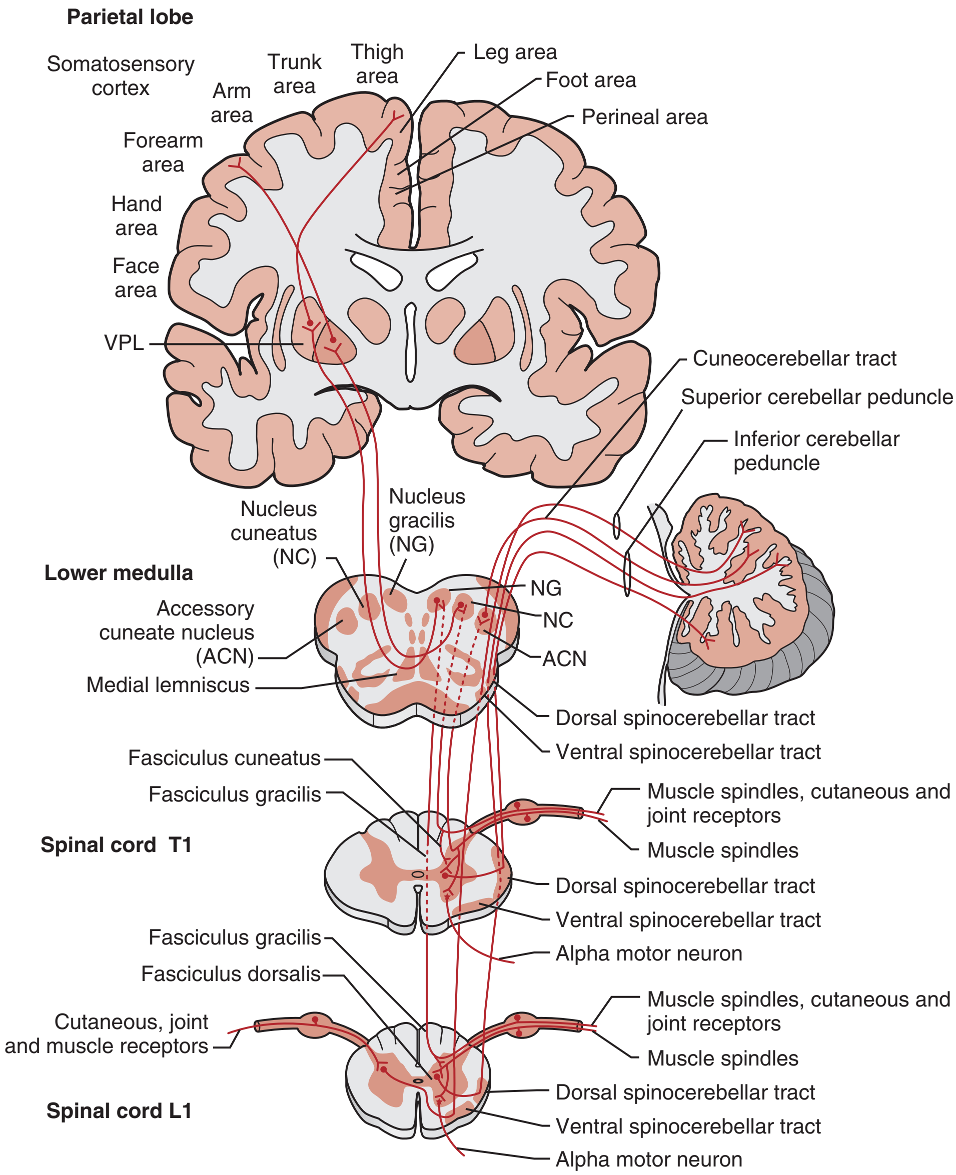

FIGURE 4-16 Spinocerebellar pathways (dorsal, ventral, and cuneo) carrying proprioceptive information from the body to the cerebellum.

Anterolateral (AL) System

The AL (Fig. 4-17) is composed of separate pathways that function primarily to transmit pain, crude touch (the detection of an object's position but not its movement across the skin), and temperature. Neutral warmth and the "tickle" sensation are also related to transmission within these anterolateral pathways. The term **anterolateral system** is sometimes used interchangeably with **spinothalamic pathway** because the thalamus is a major projection point for many fibers traveling in the anterolateral fasciculus. In fact, some texts have indicated that the AL is but one pathway, the spinothalamic pathway, with intermediate projections to the reticular formation, cranial nerve nuclei, and parts of the mesencephalon and hypothalamus on the way to the thalamus. Individual projections are sometimes classified as specific pathways (spinothalamic, spinoreticular, spinobulbar, spinomesencephalic, and spinohypothalamic) but sometimes not. Determining which nomenclature is correct is beyond the

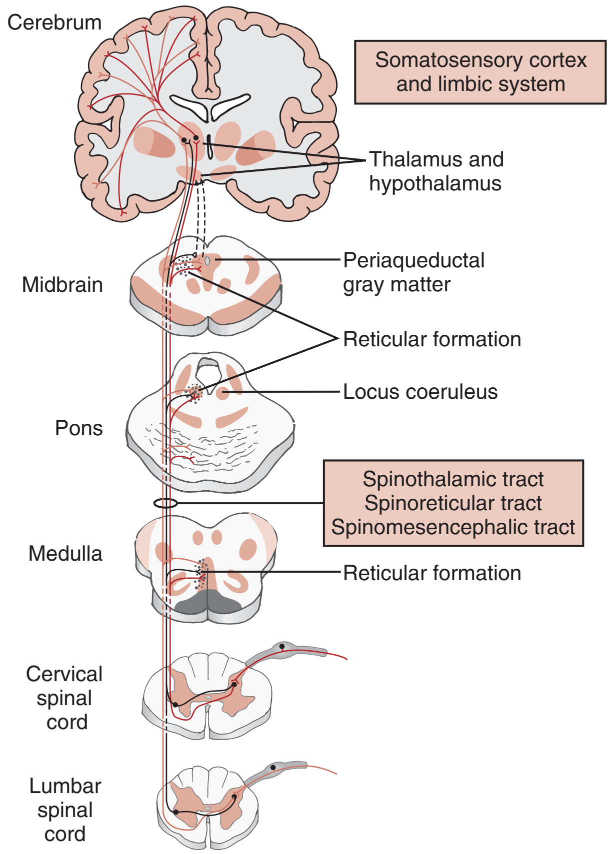

FIGURE 4-17 The anterolateral pathway consists of several fiber pathways. Shown here are the spinoreticular, spinomesencephalic, and spinothalamic.

scope of this text. For clarity in identifying the beginning and end of the projections, we will use the individual pathway designations.

Receptors for the AL system include those that respond to rough stimuli (e.g., rubbing, squeezing, pinching) that do not result in tissue damage as well as those that do respond when tissue is damaged. These latter receptors are **mechanonociceptors.** When tissue is damaged, the release of chemical substances activates a third class of receptors, called **chemonociceptors.** There are also receptors for sensations of cold and heat. None of these receptors localizes inputs well when compared with receptors associated with the DCML.

As with the DCML, cell bodies for neurons associated with the AL are in the dorsal root ganglion. Projections from dorsal root ganglion cells enter the spinal cord, and the fibers ascend or descend one or two spinal segments before synapsing in the dorsal horn. The interconnections of these fibers can be complex. After synapsing, the majority of second-order neurons cross to the other side of the cord and project to the brainstem reticular formation and the thalamus. The crossing pattern defines a different picture for injury or dysfunction than that seen for the DCML. Any injury to this system above the level of fiber entry into the spinal cord results in deficits on the opposite side of the body.

As suggested by the pathway names, information carried within the AL system projects to the reticular system (spinoreticular), thalamus (spinothalamic), periaqueductal gray and the tectum (spinomesencephalic), and hypothalamic (spinohypothalamic) areas. Interestingly, a large portion of fibers within the AL terminate within the reticular formation. The transmission of both diffuse and chronic pain is thought to be projected to this area of the brain, where arousal is associated with pain. Spinothalamic projections carrying nonspecific touch, temperature, and pain go to the VPL as well as other thalamic nuclei. The thalamus also receives tactile projections from the reticular formation. Fibers sent to midbrain regions (periaqueductal gray and tectum) and the hypothalamus permit information about pain to become available to the limbic system and the ANS, generating emotional, neuroendocrine, and cardiovascular responses to pain. Interestingly, the emotional components of pain can be separated from pain perception, probably because of the variety of projections within the AL. Medications in the benzodiazepine class (e.g., Valium), when used for pain, do not mask pain perception. Instead, they make the sensation of pain less distressing through their action on the limbic system. Projections to the tectum may be associated with the visual (superior colliculus) and auditory (inferior colliculus) systems; however, the tectum is also an important center for pain reception.

Perception of pain relies on projections to the VPL of the thalamus, where it may be interpreted as paresthesia or dull pain and pressure. Pain projections in the thalamus are more widespread than those from the DCML, and the projections for pain and touch remain segregated (Bear et al., 2015). Projections from the VPL go to the somatosensory cortices (both S-I and S-II), which, therefore, are also potential anatomic sites for interaction between DCML and AL inputs. Precise localization of pain is thought to take place at the cortical level.

Somatosensation from the Face

The trigeminothalamic pathway (Fig. 4-18) transmits tactile and proprioceptive input from the face. The cell bodies for the fibers in the peripheral aspect of this pathway are located in the trigeminal ganglion. From there, fibers project to the pons and the spinal cord, where they both ascend and descend before synapsing. Fibers carrying pain and temperature information form the spinal trigeminal tract. From there projections go to the contralateral ventral posterior medial thalamic nucleus and onto the primary and secondary sensory cortices; these projections provide the discriminative aspect of facial pain. The affective aspects of pain follow pathways to the reticular formation, areas in the midbrain, and midline thalamic nuclei, which then connect with the cingulate gyrus. Pain and temperature information from the face are also transmitted by way of the facial, glossopharyngeal, and vagus cranial nerves, VII, IX, and X, respectively.

Cell bodies for neurons carrying proprioceptive information from muscles of the face are found in the mesencephalic trigeminal nucleus, located in the midbrain. From here, this information projects to the thalamus and on to the primary sensory cortex, where the regions around the mouth have a wide representation. The sensory homunculus reflects this wide representation.

Functional Considerations

In SI theory, the tactile system is thought to be of the utmost importance in determining behavior. The sensation of touch is, in fact, the "oldest and most primitive expressive channel" (Collier, 1985, p. 29), and it is a primary system for making contact with the external world. We are extremely dependent on touch until language, motor skills, and cognitive processes develop and can guide our experiences and interactions (Collier, 1985; Diamond & Hopson, 1998). Touch has been called our first language; it is the first system to function *in utero,* and it mediates our first experiences in this world. We are nourished, we are calmed, and we first become attached to others (i.e., bonding) through touch (Montagu, 1978). The somatosensory system differs from other sensory systems in that the receptors are widely distributed (Bear et al., 2015), a fact that has potential ramifications from a sensory integrative perspective; we can close our eyes when light is too bright or put fingers in our ears to block out sound, but it is very difficult to effectively "turn-down" tactile input. This system also differs in that it responds to multiple types of sensation rather than the more unitary responses seen with other sensory systems.

In a review of literature, Blackwell (2000) summarized the power of the tactile sensory system:

> There remains little doubt that tactile stimulation is an important factor in the social, emotional, physiological, and neurological development of infants and young children. Consequently, it is one of the most essential elements in the nurturing and healing environment of the infant and child. (p. 37)

With widespread receptors that respond to several different types of input, the potential

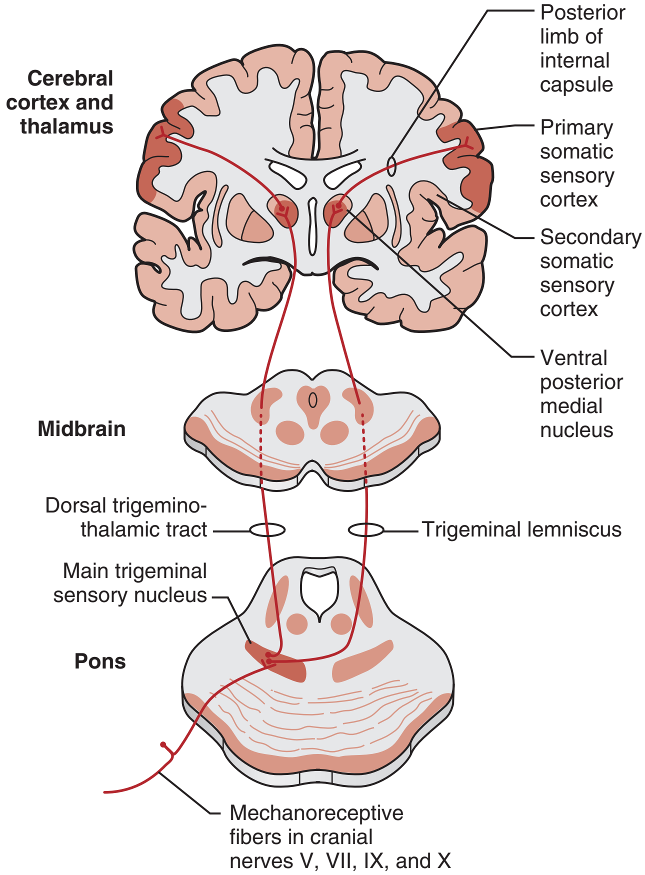

FIGURE 4-18 Trigeminothalamic pathway. This pathway carries light touch, pain, temperature, deep touch, and proprioception from the face to the thalamus.

for multiple occupational roles to be disrupted by inadequacies in processing tactile input is worth considering. For example, a difficult time with performance of activities of daily living (ADLs) may be related to inadequate integration of input from tactile receptors responsible for discrimination. Poor student performance may result from difficulty manipulating writing and cutting tools in the classroom. Poor peer interactions may result from inadequate modulation of tactile sensation. Many aspects of touch associated with tactile defensiveness are hypothetically associated with transmission through the AL pathways and with the central interpretation of the input (Ayres, 1972). Given that the AL pathways project to the regions of the brain responsible for arousal (reticular system), emotional tone (limbic structures), and autonomic regulation (hypothalamus), we postulate that tactile-defensive behaviors may be related to the connections among these systems and brain regions. Tactile over-responsivity is discussed in more detail in Chapter 6 (Sensory Modulation Functions and Disorders).

Although functionally it appears that the DCML and the AL are separate and discrete, considerable functional overlap can be seen. For example, the DCML plays an important role in the localization of pain. Furthermore, children with lesions in the DCML retain some skill in tactile discrimination. Thus, some information about pain is transmitted through the DCML, and some aspects of tactile discrimination must be carried in the AL. Many authors have discussed this redundancy of function in terms of parallel pathways and serial processing. Parallel pathways are advantageous because they add to the depth and flavor of a perceptual experience by allowing the same information to be handled in different ways, and they offer a measure of insurance. If one pathway is damaged, the other can provide residual perceptual capability. Such functional redundancy in the organization of the nervous system may play a role in the efficacy of intervention.

Proprioceptive inputs to the cortex combine with tactile inputs to support the somatotopic mapping associated with this region. In fact, in the sensory cortex there are four complete maps of the body (homunculus), one each in area 3a, 3b, 1, and 2; recent research has identified area 3b as the primary sensory cortex. Maps in each of these regions reflect the density of sensory receptors on the body. Because there is greater density of receptors in regions where more precise information is required for function, these regions appear large in the homunculus. The area associated with the hand, for instance, is quite large, and the thumb/index region even larger. Similarly, the area associated with the mouth is disproportionately large, reflecting the important role that somatosensation plays in speech and eating. As noted earlier, area 3a receives substantial proprioceptive input, giving it a primary role in the sense of body position.

Proprioceptive inputs to the cerebellum contribute to our ability to monitor and adjust movement as it takes place. The cerebellum has an error correction function, resulting in our ability to make changes in motor output to meet changing environmental demand. Proprioceptive inputs then support the comparator function of the cerebellum, allowing the cerebellum to compare the plan for action with the action itself as it unfolds. The end result of this process is the production of smooth, coordinated, multi-joint action. When there is damage to the spinocerebellum, disrupting the processing of proprioceptive input and feedback, it may be seen as a wide, shuffling gait, difficulty performing rapid alternating movements, and over- and under-reaching. Interestingly, cerebellar inputs remain ipsilateral; this means that when there are cerebellar deficits, they are seen on the same side of the body. This is in contrast to the processing of proprioception at higher levels, which is contralateral.

HERE'S THE POINT

- Receptors for touch are found primarily in the layers of the skin; those for proprioception are found in muscles, joints, and tendons.
- Somatosensory information from the body travels from receptors to the cerebellum (spinocerebellar pathways for proprioception), regions of the reticular formation, hypothalamus, limbic system, and thalamus (anterolateral system and dorsal column medial lemniscal pathway), and from the thalamus to the primary and secondary sensory cortices, as well as areas 5 and 7 of the parietal lobe.
- Somatosensory information from the face is carried by the trigeminothalamic pathway to the thalamus and from there projects to regions of the cortex for the somatosensation from the body.
- Somatosensory receptors are pervasive throughout the head and body; their central influences are broad. These characteristics support widespread influence of this sensory input on occupational engagement and participation.

Interoception

Although the perception of sensation relative to the internal body has not been a focus of SI, it warrants consideration here. **Interoception** involves sensing the physiological condition of the body. Thus, we are aware of such internal sensations as hunger, satiety and thirst, heartbeat, and visceral sensations. As will be discussed next, the interoceptive pathways function in conjunction with motor and autonomic pathways, giving us the ability to have an internal sense of self and a means of acting on the environment.

Receptors and Transduction

We have already addressed one set of receptors for this system; they include the tactile receptors described previously for the anterolateral pathway. This may seem counterintuitive; although Sherrington (1906) first coined the term *interoception* to include only information from the interior of the body (viscera), more recently Craig (2002, 2009) indicated that we needed to broaden our definition of this term to include all sensory inputs that provide the CNS with information regarding how the body, internal and external, feels. Receptors in our internal organs and blood vessels, schematically shown in Figure 4-4, include free nerve endings, mechanoreceptors, chemoreceptors, and thermoreceptors. Cell bodies of primary afferent neurons reside in spinal and cranial nerve ganglia. Interoceptive input travels to the CNS over small diameter fibers, and it provides us with an understanding of our internal state.

One rationale for including skin receptors as interoceptors has to do with their role in providing the CNS with information about the state of the body; another rationale has to do with how the receptors are activated and how this information is transmitted. In contrast to other somatosensory input, sensations of pain, itch, or temperature can be activated by *internal* stimuli as well as external or mechanical stimuli. And they are activated continuously, providing us with ongoing information about our physiological state. Interoceptive signals, such as pain, temperature, and itch sensation, as well as other chemical and hormonal signals, are projected to the spinal cord over relatively small fibers. As such, interoceptors are the basis for homeostasis.

Interpreting Interoceptive Input

The projection target for interoceptive fibers entering the cord is in one particular region, lamina 1 (Fig. 4-19). Within lamina 1 are modality-specific cells that respond to changes in blood chemistry (e.g., oxygenation, glucose levels), hormone levels, and by-products from muscle activation. Fibers projecting from lamina 1 go to autonomic cell columns and homeostatic centers in the brainstem. In the brainstem, tactile information from the body is joined by sensory information from the heart, viscera, tongue, and pharynx, conducting information related to such

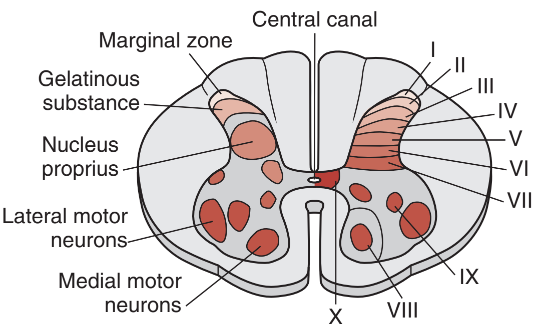

FIGURE 4-19 A cross section of the spinal cord showing spinal lamina (left) and associated labels for cell groups (right).

things as taste, thirst, nausea, and dyspnea (difficulty breathing), projecting to the solitary nucleus in the medulla. The combination of these two sources of interoceptive input forms what is considered the **afferent** or input aspect of the ANS, allowing us to map an internal awareness of self and integrate sensation related to functions of the ANS and homeostasis. Multiple connections take place in the brainstem, and from here these integrated sensations are sent to the hypothalamus, amygdala, and thalamus. The hypothalamus is the seat of autonomic regulation and homeostasis. Activation of the cells in this structure leads to hormonal, visceral, and somatic motor responses designed to re-establish the body's status quo. Hypothalamic hormones are responsible for negotiating signals reflecting changes in temperature, thirst, hunger, sleep, stress, mood, and sex drive. The amygdala is linked with fear conditioning, regulating our autonomic and emotional responses to environmental danger. Projections of interoception then continue to the insular cortex, where research has identified sensory maps of the body, and groups of cells with some differential responsiveness, that define distinct sensations (such as sharp pain) and less distinct interoceptive sensations (such as gastric distention) (Craig, 2015). This region of the cortex is linked with actual and perceived stimulus intensity and, consistent with its role in interoception, tracking the body's physiological state (Uddin & Menon, 2009). The insula is also important in attaching emotional significance to body state (for instance, a rested body state may be associated with feeling happy), and in our awareness of environment, self, and others (Craig, 2009). These sensations are linked with homeostasis, and they guide emotional behaviors. There are also interoceptive projections to the anterior cingulate cortex, termed the **limbic motor cortex,** guiding action in homeostasis.

Functional Considerations

Recent research suggests deficits in interoceptive processing in individuals with autism spectrum disorder (ASD) (Elwin, Schröder, Ek, & Kjellin, 2012; Fiene & Brownlow, 2015). Participants in the study by Elwin and colleagues indicated they experienced over-responsivity to external sensation and under-responsivity to inner/body sensation. The work of Fiene and Brownlow extended these findings, looking more specifically at internal body awareness in individuals with ASD. These investigators found reduced awareness of the body and feelings of thirst in adults with autism. The anterior insula, a region thought to process interoceptive input, has been shown repeatedly to be under-active in individuals with ASD (see Di Martino et al., 2009 for meta-analysis). Regions of the insula, along with the anterior cingulate cortex, are also linked with empathy. Individuals with autism, as well as typical individuals with lower empathy, show decreased activity in the anterior insula, leading Uddin and Menon to suggest that these limbic-system-linked structures function in social and emotional responses relative to both the self and others. Given the importance of interoception for homeostatic regulation and its apparent contributions to social functioning, a better understanding of interoceptive processing and its relationship to processing within other sensory systems and functional behaviors is warranted.

HERE'S THE POINT

- Interoception, the sense we have of the physiological condition of the body, is detected by receptors in our internal organs and subsequently projected to the spinal cord and onto the brainstem, forming the afferent arm of the ANS. Some tactile inputs are linked to interoception.
- From the brainstem, interoceptive information is sent to the hypothalamus, thalamus, and amygdala and then on to the insular cortex. These connections subserve our knowledge of our body's physiological state, link this with emotion, and provide us with an awareness of the environment.
- Under-responsiveness to interoceptive signals has been identified in individuals with ASD.

The Vestibular System

We approach the vestibular system in the same manner as the somatosensory system, beginning with receptor structure and function and then examining vestibular projections within the CNS. Similar to other sensory systems, there are both peripheral and central components to the vestibular system, comprised of the receptors and vestibular nerve fibers (peripheral) and the vestibular nuclei and multiple projection pathways (central). Following the vestibular system, we will discuss proprioception from a functional perspective and briefly look at the interaction between vestibular and proprioceptive sensation as they relate to the control of posture and movement.

Receptors and Transduction

The vestibular apparatus sits inside the body labyrinth within the temporal bone, adjacent to the cochlea (Fig. 4-20). It includes the semicircular canals and the otolith organs, the utricle and the saccule (Fig. 4-21). Receptors for the vestibular system are located within these structures in the inner ear, and the endolymph that bathes the receptors for the auditory system moves freely between the auditory and vestibular systems.

Vestibular receptors are hair cells located in the otolith organs and in swellings at the base of the three semicircular canals (i.e., anterior, lateral, posterior). The otolith organs are responsible primarily for static functions, concerned with head translation and changes in head position relative to gravity. The information processed by these receptors is used to detect the position of the head and body in space as well as control of posture. The semicircular canals are the dynamic component of the vestibular system, responding to rotation and angular movement of the head. These structures respond to movement of the head in space.

Vestibular receptors are chalice-shaped with hair-like processes extending from their apices. At the base of each cell lies the afferent process of the vestibular nerve fibers. The vestibular component of the vestibular-auditory cranial nerve is formed from the axons of these fibers. Each cell has a single kinocilium and several stereocilia. Although movement of the kinocilium in one direction leads to depolarization of the hair cell, movement in the opposite direction leads to hyperpolarization. Hair cells within each semicircular canal have a specific orientation such that they are all depolarized or hyperpolarized by movement in one direction. Cells in the otolith organs are also polarized, but, because of the structure of these organs, cells respond to a vast array of directions of movement. When the otolith cells depolarize, glutamate, an excitatory

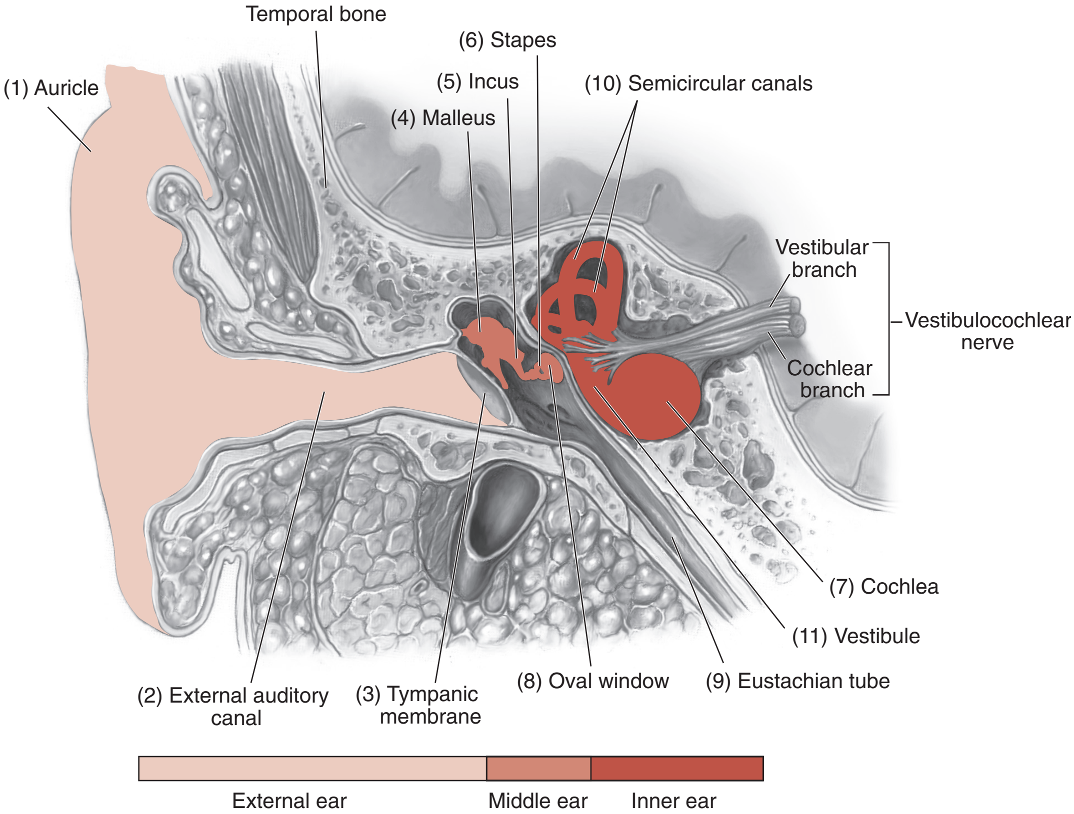

FIGURE 4-20 Vestibular and auditory receptor systems are both located in the temporal bone, in close proximity to each other.

neurotransmitter, is released into the synaptic cleft. The transmitter interacts with the afferent fiber of the vestibular nerve, sending information about movement to the CNS (Soto & Vega, 2010). We discuss the specifics of depolarization within the semicircular canals and otolith organs next.

In addition to the afferent fibers at the base of each hair cell, there are also efferent fibers that originate in the vestibular nuclei. These efferent fibers provide inhibitory control of the transmission of information from the hair cell and can prevent information from traveling beyond the receptor site.

Utricle and Saccule

The otoliths are saclike organs oriented in horizontal and vertical planes (Fig. 4-21). In the macula, which is the receptor region of the otolith organs, hair cells synapse with processes from the vestibular ganglion cells. Hair cell processes extend into an overlying substance with gelatin-like qualities, the otolith membrane, in which are embedded otoconia (calcium carbonate crystals). In the upright position, the hair cells in the macula of the utricle are oriented in a horizontal plane, whereas those of the saccule are oriented in the vertical plane. In both sets of organs, the otoconia rest on top of the hair cells. When the head tilts or moves in any plane (side to side, up/down, forward/backward), there is displacement of the otoconia and the embedded hair cell stereocilia, beginning the process of stimulus detection and transduction. Movement of the stereocilia creates electrical discharges within the hair cell. This electrical energy is changed to chemical energy at the synapse between the macular hair cells and the vestibular ganglion projections. Thus, together, the utricle and saccule respond to head tilt in any direction and to linear movement. It is important to remember that we get directionality because the system is bilateral and these structures are paired; activation on one side of the head is matched with inhibition on the

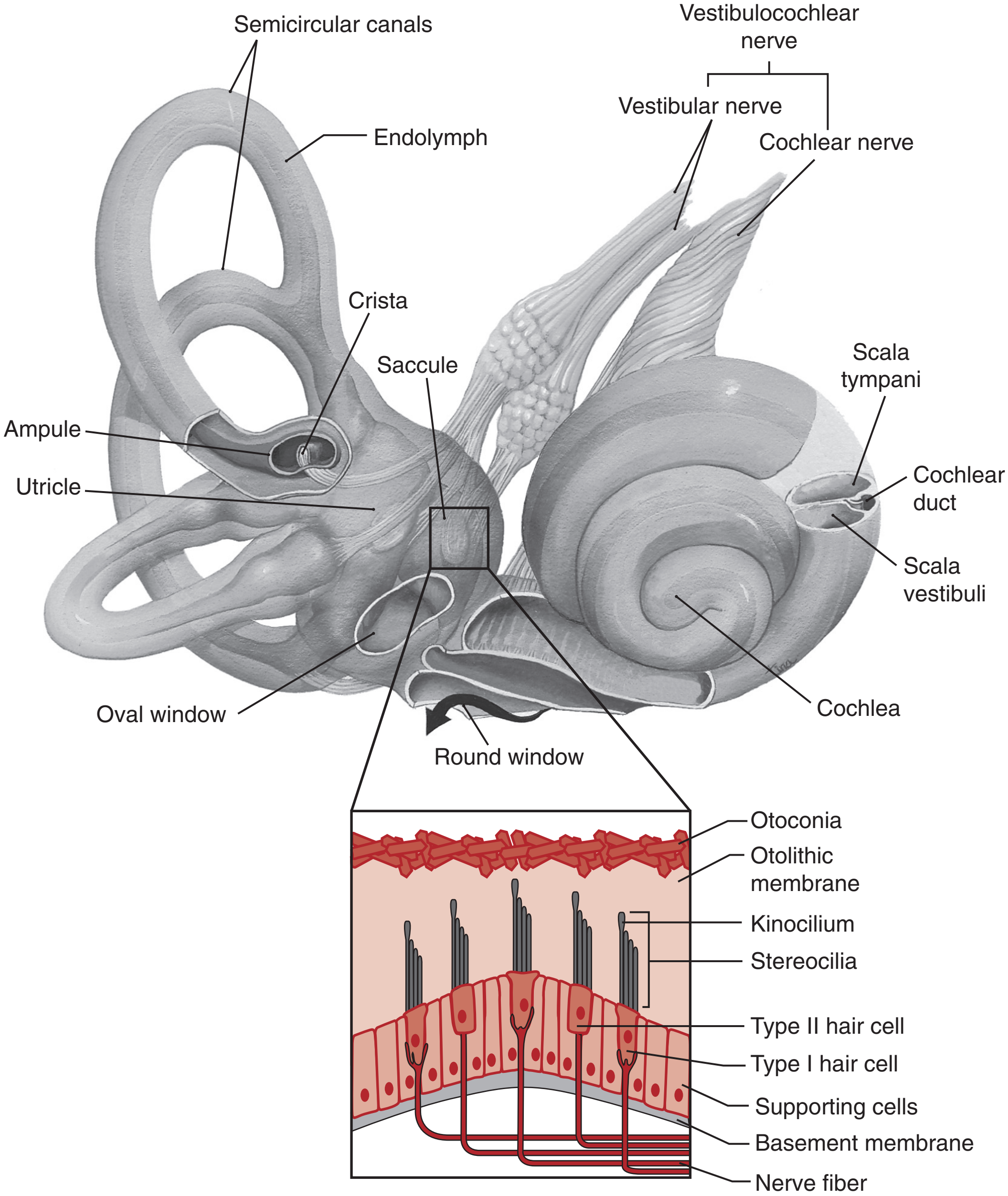

FIGURE 4-21 Structures of the inner ear. The vestibular apparatus on the left side of the image shows three semicircular canals as well as the receptor region in the ampulla at the swelling of one of the canals. Within the ampulla is the crista, which consists of the hair cells and the overlying gelatinous mass, called the cupula. The otolith organs, the utricle and the saccule, are also identified. Within the saccule, the macula, or receptor region, is shown.

other side of the head. The otolith maculae constitute slow-adapting receptors and provide tonic input to the CNS pertaining to head position and movement. The tonic input is crucial in supporting upright posture and equilibrium.

Semicircular Canals

The semicircular canals (Fig. 4-21), which are actually closed tubes, detect changes in the direction and rate of angular acceleration or deceleration of the head. Angular acceleration results in rotary head movements—that is, head movements that, if continued far enough, would result in the head turning in a circle (e.g., spinning, head nodding). Within each vestibular apparatus, the three semicircular canals are oriented at right angles so that they represent all three planes in space. When the head is tilted forward 30 degrees, the horizontal canal is oriented in the horizontal plane, with the anterior and posterior canals positioned vertically and oriented at right angles to each other.

The semicircular canals have an enlarged ending called the **ampulla.** Within the ampulla is the receptor apparatus for the semicircular canals, the crista ampullaris, which contains the hair cell receptors. The receptors are embedded in the cupula, a substance with gelatin-like characteristics similar to the macula. There are no otoconia in the crista ampullaris. Instead, the cupula extends nearly to the top of the ampulla, and its edges are, for the most part, anchored to the epithelium that lines the canal. The canals are filled with endolymph. When the head moves (accelerates), inertia causes the endolymph to lag behind head movement. This is often paralleled with swirling water in a glass; when you begin to swirl the glass, you can see that water "lags" behind the speed of movement of the glass. If you continue to swirl, the water speed will catch up, and the glass and water will move "as one." In the semicircular canals, the initial lag results in pressure on the cupula and its displacement in a direction opposite to that of head movement. Displacement of the cupula leads to bending of the hairs, and this mechanical distortion begins the process of transduction. As head movement continues, the speed of the endolymph catches up with that of the head, the cupula returns to its resting position, and the hair cells are no longer mechanically distorted. With continued movement of the head at a relatively constant velocity, the semicircular canal receptors return to a basal firing rate. When head movement stops or decelerates, the inertia again acts on the endolymph, and it continues to move in the canals, this time in the direction of head movement. Again, pressure is placed on the cupula, bending the hairs in the same direction in which the head had been moving. This then changes transmission and activity in the vestibular nerve. Several seconds after the head stops moving, the cupula and hairs return to their normal resting positions.

As is the case for the otolith organs, the semicircular canals are paired structures. The horizontal canal on one side is paired with the horizontal canal on the other side of the head, whereas one anterior canal is paired with the posterior canal on the opposite side of the head. The alignment of hair cells in the crista ampullaris of each member of the pair is opposite, so when the hair cells on one side are excited, those in the matching canal on the other side are inhibited. As was the case with the otolith organs, this orientation and pairing provides directionality to movement.

Afferent and efferent fibers meet the hair cells at their base. Afferent fibers carry information from the receptors to the vestibular ganglion, and, from there, fibers join to become the vestibular nerve (Fig. 4-21), one part of cranial nerve VIII, the vestibulocochlear nerve. The vestibular fibers project to the vestibular nuclei. Efferent input from the nuclei may form part of an early feedback mechanism within the vestibular system or may serve to guide typical development of vestibular structures (Baloh & Kerber, 2010). Investigation continues to be warranted on the precise function of these efferent fibers; however, output from these fibers results in modification and, potentially, modulation (Holt, Lysakowski, & Goldberg, 2011).

Because the hair cells in each pair of canals are maximally stimulated by head rotation in the same plane, they are able to detect movement of the head in the three orthogonal (right-angle) planes of three-dimensional space. The most efficient stimuli for the semicircular canals are angular, transient (short-term), and fast (high-frequency) head movements of at least 2 degrees per second. When the head moves at slower speeds, the endolymph, cupula, and hair cells all move at the same speed as the head. As such, the cupula does not bend, and hair cells in the ampulla are not activated.

As noted earlier, the otolith inputs are a foundation for upright posture and equilibrium because these inputs are tonic. Semicircular canal inputs are phasic; sensory information is sent only as long as the cupula bends the hair cells. These inputs then are important in triggering righting responses, supporting our ability to master perturbations from movement in and through the environment. Afferent fibers in the vestibular nerve transmit both tonic and phasic information from the receptors, which is critical to function within this system.

Central Projections

There is always some activity within the vestibular nerve, primarily because of tonic activation of otolith organs by gravity. Activation of the receptor organs either increases or decreases this baseline activity, depending on the type and direction of movement. Activation in one half of the pair of canals is met with decreased activity in the parallel canal on the other side of the head. Because the vestibular nerves project both ipsilaterally and contralaterally, the vestibular nuclei interpret direction of movement by comparing the frequency of impulse flow between left and right canals and otolith organs.

The cell bodies for the vestibular nerve are located in the vestibular nerve ganglion, also known as **Scarpa's ganglion.** From these cell bodies, the vestibular nerve carries information to the vestibular nuclei in the brainstem. There are four nuclei on each side: lateral, medial, superior, and inferior (Fig. 4-22 panel A). A great deal of sensory processing takes place at this level within the vestibular system. Each nucleus receives direct ipsilateral input as well as contralateral input via fibers crossing from the opposite nuclei. These nuclei also receive inputs from the spinal cord, cerebellum, and visual system. The organization of these inputs allows detection of direction and speed of head movement as well as position of the head relative to gravity.

Vestibular nuclei receive input from other sensory systems, notably the visual system. According to Purves and colleagues (2011), this makes the vestibular system unique among sensory systems; there is multisensory integration in the first site of central vestibular processing and throughout all subsequent projections. Visual inputs are relayed through the inferior olive and cerebellum, and the interaction of these inputs is thought to be important in generating eye movements, as described later.

From the vestibular nuclei come many fiber pathways that connect the vestibular system extensively within the CNS. Direct connections are found between vestibular nuclei and the cerebellum, oculomotor nuclei, and spinal cord. Projections have also been described to parts of the reticular system, the thalamus, and the cortex (frontal lobe, parietal-insular cortex). This organization within the vestibular system is an example of heterarchical processing rather than hierarchical; each connection has a unique function.

Vestibular-Cerebellar Connections

The vestibular system is the only sensory system with direct connections from receptors to the cerebellum. Projections come from the vestibular nerve directly (Fig. 4-22) and from vestibular nuclei. In turn, there are direct connections from the cerebellum to the vestibular nuclei. These reciprocal connections from the cerebellum go primarily to the medial and lateral vestibular nuclei. As noted later, ascending fibers from the medial vestibular nucleus project to oculomotor nuclei, allowing the cerebellum to influence eye position; descending projections from this same nucleus give the cerebellum control of head and neck movements (Fig. 4-22 panel A). Reciprocal connections between the cerebellum and the lateral vestibular nucleus influence output over the lateral vestibulospinal pathway, thus influencing postural control. Together then, the vestibular system and the cerebellum coordinate eye, head, and trunk movements and are critical for posture, balance, and equilibrium.

Vestibulospinal Connections

The vestibular nuclei send projections to the spinal cord via lateral and medial vestibulospinal pathways (LVST and MVST, respectively; Fig. 4-22 panel A). These pathways are responsible for influences on muscle tone as well as for ongoing postural adjustments. The LVST receives input from semicircular canal pairs, otolith organs, the vestibulocerebellum, and the spinal cord. Fibers from the LVST terminate directly on alpha and gamma motor neurons in the spinal cord at the cervical, lumbar, and sacral levels. Alpha motor neurons supply muscle fibers, and gamma motor neurons project to the muscle spindle; thus, the vestibular system has a strong influence on postural muscles, postural control, and stability. The MVST receives input from the cerebellum and from skin and joint proprioceptors. The fibers in this pathway project to flexor and extensor motor neurons in the cervical region of the cord. This input assists with the maintenance of a consistent position of the head in space. Thus, with descending vestibular

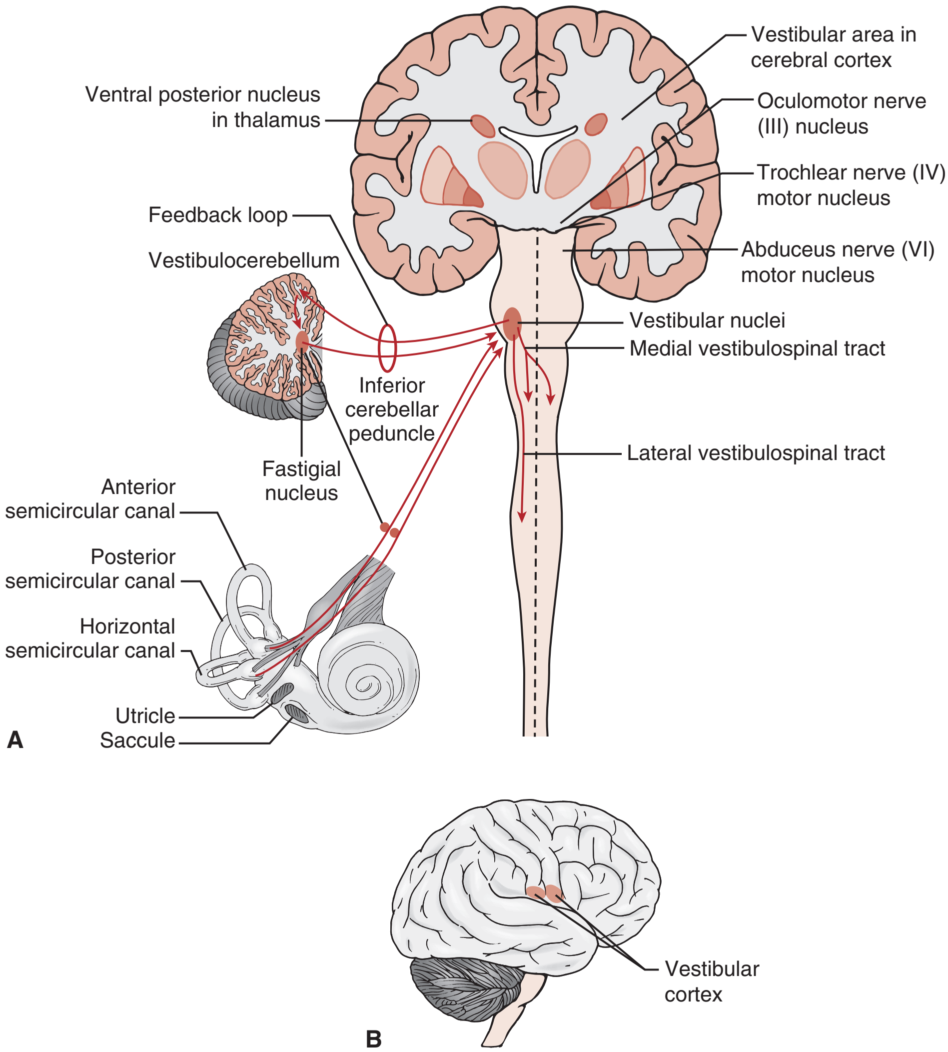

FIGURE 4-22 A. Central vestibular connections. Ascending fibers connect with oculomotor nuclei to coordinate movement of the eyes relative to the head. Vestibular projections are also found to the thalamus and on to regions in the cortex. The vestibular system has a reciprocal connection with the cerebellum, and fibers descend to the spinal cord as the medial and lateral vestibulospinal pathways. B. One of the cortical projection regions of the vestibular system, found at the base of the precentral gyrus and the intraparietal sulcus.

projections, we see the interaction of vestibular and proprioceptive inputs.

Responses elicited because of stimulation of the utricle or semicircular canal activate extensor muscles, eliciting compensatory movements of the head, trunk, and limbs. Such movements help oppose head perturbations, postural sway, or tilt and keep us upright (Fisher & Bundy, 1989; Goldberg et al., 2012). However, as might be expected, there are differences between the kinds of postural responses ultimately elicited by stimulation to the different receptors. Utricular inputs, conveyed primarily via the LVST to limb and upper trunk alpha and gamma motoneurons, result in ipsilateral facilitation of extensor muscles and inhibition of flexor muscles. Semicircular canal inputs are conveyed primarily via the medial vestibulospinal pathway to axial alpha and gamma motoneurons and result in bilateral facilitation of neck and upper-trunk flexor muscles. Functionally utricular inputs elicit more sustained postural responses (i.e., tonic postural extension and support reactions); semicircular canal inputs elicit more phasic equilibrium responses (Fisher & Bundy, 1989; Roberts, 1978; Wilson & Melvill Jones, 1979).

Functionally then, if the goal is to facilitate tonic postural or support reactions, activities that provide utricular stimulation may be more appropriate. If the goal is to encourage the use of more phasic or transient postural reactions, then activities that provide stimulation to the semicircular canal may be indicated.

Vestibular-Oculomotor Connections

Vestibular fibers directly project to oculomotor nuclei for cranial nerves III (oculomotor), IV (trochlear), and VI (abducens) via the medial longitudinal fasciculus (Fig. 4-22 panel A). Fibers are both crossed and uncrossed as they reach these nuclei. These connections serve to provide an ongoing stable visual image; as the head turns in one direction, eye movement occurs in the opposite direction, preventing retinal slip and maintaining visual acuity (Goldberg et al., 2012). Inputs that mediate these responses come from the semicircular canals and are active in any plane of movement. When the head is not moving, the eyes remain still. However, with head movement comes activation of the vestibulo-ocular reflex to enable the visual field to remain stable even as the head and body move.

Nystagmus is a specialized compensatory vestibulo-ocular movement. As the head moves in an angular fashion, interactions between the oculomotor nuclei and the vestibular system allow the eyes to remain fixed on an object in space. With continued angular movement of the head, the eyes reach the end of their range of motion; this comprises the slow phase of nystagmus. Once the end of range is reached, the eyes spring back to a central position; the quick movement to a central position comprises the fast phase of nystagmus. The nystagmic eye movements are tied to the movement of endolymph in the semicircular canals, which results from angular movement of the head. At the onset of head movement, endolymph movement lags behind head movement, bending the cupula in the semicircular canal as it moves. As head movement continues at a steady pace, the speed of endolymph movement catches up with the speed of head movement, and the cupula regains an upright position. This stops activation of the hair cell receptors, and input to the CNS returns to baseline.

Nystagmus is named for the direction of the fast phase, which is the same as the direction of head movement. When nystagmus occurs during head movement, it is termed **per-rotary nystagmus** (i.e., nystagmus that takes place during movement). Per-rotary nystagmus declines and eventually stops as described previously. When the head stops, endolymph in the canals continues to move in the direction of head turn. This activates the cupula again, in the opposite direction, and triggers the same sequence of events described previously but in the opposite direction, this time leading to **postrotary nystagmus.**

Measurement of postrotary nystagmus is a tool that has been used to examine one aspect of the integrity of the vestibular system. When using this measurement, it is important to have a more complete understanding of the processes underlying nystagmus. These processes were well described by Fisher (1989); we summarize them briefly here. Movement of endolymph in the semicircular canal and displacement of the cupula initiate nystagmus. However, the cupula returns to a resting position and stops activating the vestibular receptors several seconds before nystagmus ceases. This phenomenon is related to **velocity storage,** a mechanism associated with the vestibular nuclei in which velocity information generated by movement is collected and stored and then released slowly, generating nystagmus (Baloh & Kerber, 2010; Goldberg et al., 2012). Fisher, Mixon, and Herman (1986) suggested that this mechanism was impaired in individuals with a vestibular-based dysfunction in SI, resulting in shortened duration of postrotary nystagmus. Further investigation is needed to confirm this possibility.

Vestibular-Thalamic and Cortical Connections

Vestibular connections project bilaterally to the VPL of the thalamus as well as to the lateral and paramedian nuclear groups of the thalamus. The VPL receives somatosensory input and is one anatomic region where interaction of somatosensory and vestibular inputs takes place. From the thalamus, fibers project to the cortex, to the base of the precentral gyrus (area 3a), and to the base of intraparietal sulcus (area 2V) (Goldberg et al., 2012) (Fig. 4-22 panel B). Area 2V neurons respond to head movements, and activation of this region leads to sensations of dizziness or awareness of movement. Neurons here receive not only vestibular input but also visual and proprioceptive inputs, and this area is likely involved with the perception of motion and spatial orientation. A lesion here leads to confusion in spatial orientation. Area 3a receives vestibular and somatosensory inputs and projects to area 4 of the motor cortex. These connections likely serve to integrate motor control of the head and body.

The Integrative Vestibular System

By nature of the multiple connections with other sensory inputs and motor output systems, the vestibular system is a multisensory integrative system, as has been noted previously. Vestibular pathways are both unilateral and contralateral, with recent evidence indicating fibers cross at the vestibular nuclei, in the pons, the midbrain, and at the corpus callosum (Kirsch et al., 2014). The bilaterality of this system is considered crucial to its function (Rine & Wiener-Vacher, 2013). According to Dieterich and Brandt (2015), vestibular inputs are multimodal, activating other sensory systems as they are used to mediate our perception of body position in and movement through space, as well as gaze stabilization. Unique among sensory systems, the vestibular system has no primary sensory cortex; regions of the cortex receiving vestibular inputs (i.e., the parietal-insular area) also respond to other sensory inputs. The vestibular system then uses multimodal and multilevel integration in conducting its critical functions.

Vestibular and Proprioception Interactions

Vestibular and proprioceptive processing are hypothesized to contribute jointly to the perception of active movement, the development of body scheme, and the development and use of postural responses—especially those involving extensor muscles (e.g., extensor muscle tone, equilibrium). Reviewing available research at the time, Matthews (1988) indicated that, under typical circumstances, the role of proprioception was to provide the motor system with a clear and unambiguous map of the external environment and of the body. Other investigators of the time had suggested that proprioception played a role in programming and planning of bilateral projected action sequences (Goldberg, 1985). Nashner (1982) had already proposed that inputs from the vestibular system could be used to resolve vestibular-visual-somatosensory (proprioceptive) conflicts, and, as such, the two systems worked together to provide a stable frame of reference against which other sensory inputs were interpreted. These early indications of function have remained with us (Goldberg et al., 2012). Thus, vestibular and proprioceptive inputs, together with vision, provide:

- Subjective awareness and coordination of movement of the head in space
- Postural tone and equilibrium
- Coordination of the eyes, head, and body, and stabilization of the eyes in space during head movements (compensatory eye movements)

HERE'S THE POINT

- Peripheral vestibular receptors (hair cells) in the inner ear respond to linear (otoliths) and angular (semicircular canals) movement. All movement input automatically influences activity on both sides of the head.
- The central vestibular system begins with the brainstem nuclei, which themselves receive multisensory inputs.
- Vestibular inputs to the cerebellum are both direct, from the receptors, and indirect, by way of vestibular nuclei, indicating the close relationship these structures share in the production of movement.
- Projections from vestibular nuclei also include fibers descending to regions of the spinal cord and ascending to oculomotor nuclei, the thalamus, and the cortex.
- The vestibular system is a multisensory system throughout its course; it is part of a network involving vestibular nuclei, the cerebellum, proprioception, spinal cord motor neurons, oculomotor neurons, the thalamus, and the cortex in supporting its functions related to eye, head, and trunk control and body position in and movement through space.

The Auditory System

Activation of the auditory system is a complex process; sound waves are received by the external

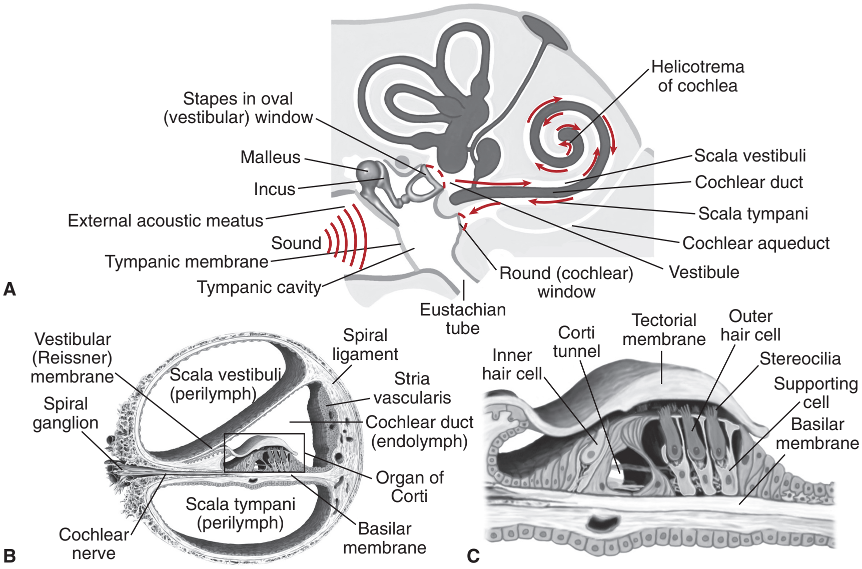

FIGURE 4-23 A. The auditory system within the temporal bone. B. Cross section through the cochlea, showing the three regions of the auditory canal. C. The organ of Corti, receptor cells for sound.

ear, transmitted via the middle ear, and finally transduced into action potentials within the inner ear. The structure of the auditory system can be seen situated in the temporal bone, adjacent to the vestibular apparatus in Figure 4-20. Receptors for the auditory system are located in the inner ear, in a membranous structure called the **cochlea** (see Fig. 4-21). The receptors are hair cells, which are components of the organ of Corti (Fig. 4-23). As you may recall, hair cells are also the receptors in the vestibular system, and the mechanism of transduction from hair cell receptors in the auditory system is similar to that described for the vestibular system.

Receptors and Transduction

Sound begins as sound waves, corralled by the external ear and transmitted through the external auditory meatus to the tympanic membrane (Fig. 4-23). Attached to the tympanic membrane are the ossicles of the middle ear. The ossicles act to optimize the transfer of sound energy from air to the fluid-filled inner ear, where the organ of Corti lies. There are two muscles in the middle ear that serve to alter responsivity of the ossicles to movement of the tympanic membrane: the tensor tympani and the stapedius. The tensor tympani is attached to one ossicle (malleolus), and it is innervated by a branch of the trigeminal nerve (cranial nerve V). The actions linked with biting and chewing lead to reflexive contraction of this muscle, pulling on the malleus and stiffening the tympanic membrane. This process effectively prevents lower frequency sound (background noise) from being transmitted and, therefore, can improve our ability to understand speech in the face of background noise. The stapedius muscle attaches to the ossicle called the **stapes;** it is innervated by the facial nerve or cranial nerve VII. The stapedius reflexively contracts with sounds at a sound pressure level of 65 dB and 500, 1,000, and 2,000 Hz, frequencies often associated with vowel sounds in speech. Reflexive contraction of the stapedius acts in a manner similar to that described previously, stiffening the tympanic membrane and blocking lower frequency sounds from entering the ear. Because of the relationship between the ossicles and the tympanic membrane, diseases that impede movement of the ossicles decrease energy transfer and interfere with hearing. This is what happens with inner ear infections (e.g., otitis media).

The transduction of sound into a neurochemical signal begins with movement of the tympanic membrane, creating a chain of events in this closed system (Fig. 4-23). Movement of the tympanic membrane creates movement of the ossicles, small bones, in the middle ear. The malleus fits into the oval window, the opening to the inner ear. Movement of the ossicles leads to movement of the oval window. As the membrane of the oval window moves in and out, it creates waves of movement in the fluid in the auditory canal of the inner ear (perilymph). Within the auditory canal is the basilar membrane; as the perilymph moves, the basilar membrane also moves. Sitting on the basilar membrane is the organ of Corti, which contains hair cells. These hair cells have projections into a second membrane, the tectorial membrane, which sits atop hair cell projections. Movement of the basilar membrane and hair cells results in bending of the hair cell projections, beginning the process of depolarization. The basilar membrane changes thickness throughout its length, being thinner at the base than at the apex. This makes it sensitive to different frequencies (i.e., pitches) along its length. The process from this point parallels that in the vestibular system. Depolarization of the hair cell releases a neurotransmitter (glutamate) that interacts with receptor sites on the afferent component of the auditory nerve, and information is carried to the CNS.

Within the auditory system, the first synapse is very close to the point of transduction, at the base of the hair cells. Activation of the hair cells turns physical energy into electrical energy and, almost immediately, chemical energy, as the impulse is transferred to the dendrites of the spiral ganglion, which synapse with the hair cells. The organ of Corti includes two types of hair cells, those thought to control the sensitivity of the receptor apparatus, the outer cells, and those thought to be responsible primarily for actual hearing, the inner hair cells. A single spiral ganglion cell may innervate as many as 50 outer hair cells. In contrast, the inner hair cells may *receive* dendritic connections from as many as 10 spiral ganglion cells. Thus, whereas outer hair cells converge, inner hair cells diverge at the first synapse in the pathway. The organ of Corti is tonotopically organized such that high sounds activate cells on the basilar membrane near its narrow end, and low sounds activate cells at the wide end of the membrane. In addition, inner hair cells and the spiral ganglion cells synapsing with them show a “tuning curve,” where there is a relationship between the amplitude of sound needed to induce a barely detectable neuronal discharge and the sound frequency. These characteristics of the receptive apparatus account for the accuracy with which sound information is transmitted to the brain.

As in the vestibular system, the auditory nerve has both afferent and efferent components. The afferent components form the cochlear portion of the vestibular-cochlear nerve (cranial nerve VIII). The efferents come from the superior olivary complex (SOC) and innervate the outer hair cells directly and the inner hair cells indirectly. When active, the efferent fibers inhibit transmission of information to the CNS and may play a role in the discrimination of specific sounds in the presence of background noise.

Central Connections

The auditory system has two primary pathways to the CNS: the **core pathway,** which maintains tonotopic organization of input and transmits sound frequency with speed and great accuracy, and the **belt pathway,** which is less well organized and transmits information relative to the timing and intensity of input. This latter pathway contributes to bilateral interaction of sound input. Information on both pathways is integrated into the information that I will describe next. Core and belt pathways project to primary (core) and secondary (belt) cortical regions. Pathways and cortical regions are described next.

Axons from the spiral ganglion cells form the cochlear nerve, which travels from the ear to the brainstem where it synapses with ventral and dorsal cochlear nuclei, ipsilaterally. All fibers have synapses in both nuclei. The tonotopic organization of these connections is maintained at this level. From this point, three routes carry acoustic information onward. From the dorsal cochlear nucleus come fibers that cross to become part of the lateral lemniscus. From the ventral nucleus, one group of fibers follows those of the dorsal nucleus, also becoming part of the lateral lemniscus. Another group passes to the ipsilateral and contralateral nuclei of the trapezoid body and the superior olivary nuclei and, from there, joins the lateral lemniscus. Thus, the lateral lemniscus has both ipsilateral and contralateral representation of acoustic information, although contralateral fibers predominate. The superior olive is the first place where information from both ears converges. This convergence occurs with accurate representation of the timing of auditory input to the two ears, which is continued onto the cortex.

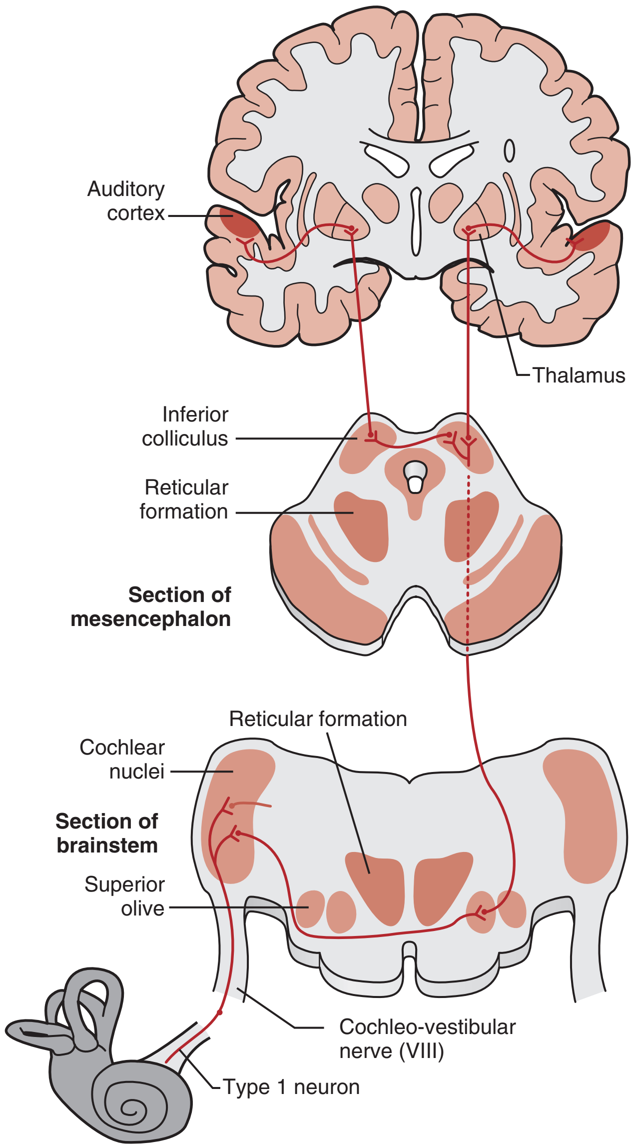

FIGURE 4-24 Central auditory pathways. Some auditory fibers project in the inferior colliculus, whereas others project to the medial geniculate nucleus of the thalamus and on to the auditory cortex.

Stimulus localization depends on the accurate rendition of the temporal aspects of sound reception (Fig. 4-24).

Fibers within the lateral lemniscus travel to the inferior colliculus and the medial geniculate body. The inferior colliculus receives essentially all auditory input, both core and belt pathway input, as well as input from the contralateral auditory cortex. As such, it is a major integrating center for the auditory system. The main nucleus of the inferior colliculus is the central nucleus, where cells are sensitive to both timing and intensity differences in the sound transmissions received; this structure then functions in detecting both sound frequency and sound temporal characteristics. Regions of the inferior colliculus are also sensitive to differences in time of arrival of sound, giving it a role in sound localization and binaural hearing (Sahley & Musiek, 2015). Another site for auditory input in the inferior colliculus is the paracentral nucleus. This structure receives not only auditory input but also inputs from the spinal cord, dorsal column, and SC. This nucleus is thought to play a role in multisensory integration and auditory attention.

The inferior colliculus sends fibers on to the medial geniculate body, a specialized nucleus within the thalamus. From there, information travels to the transverse temporal gyrus, also called Heschl gyrus, occupying Brodmann areas 41 and 42 within the primary auditory cortex. It receives input from the core pathway and is tonotopically organized. The belt area surrounds the area of core pathway input; it is both less organized and less well understood. When information reaches the primary auditory cortex, a sound is heard and interpretation begins. The primary auditory cortex receives both ipsilateral and contralateral input, further supporting the mapping of sound. Neurons in this area also map loudness, modulation of loudness, and modulation of frequency (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2013). This cortical region is critical for the perception of speech.

Brodmann area 22 (Fig. 4-7) corresponds to the secondary auditory cortex, where discrimination of location and direction of sound take place. The secondary auditory cortex receives input from the paracentral nucleus of the inferior colliculus. As noted, this projection is likely responsible for detecting and directing attention to auditory input that is novel or moving. The planum temporale is a part of this area, and it is an area implicated in dyslexia. It is an area that shows bilateral asymmetry, with somewhat different functions for each side. The planum temporale plays a role in processing complex sound as well as processing basic auditory input and speech (Liem, Hurschler, Jancke, & Meyer, 2014). Area 22 also receives input from the visual and somatosensory pathways.

The auditory association cortex encompasses areas 39 and 40 (Fig. 4-7), the angular gyrus and supramarginal gyrus, respectively. These areas are associated with reading and writing. Damage to area 39 leads to an inability to recognize speech. Projections from the primary auditory cortex are also found in other cortical regions associated with speech. Areas 44 and 45 have been called the Broca area; damage in that area results in speech that is nonfluent, although speech recognition is not impaired by such damage. The association area of the auditory cortex also receives input from other systems, such as the vestibular and somatosensory systems. Thus, there is multisensory interaction here, and this may play a role in arousal or attention.

Efferent Processes and Feedback Loops

Within the auditory pathways are numerous efferent processes thought to act as feedback loops. Functionally, they may contribute to selective auditory attention. Reticulospinal pathways "sample" activity in the lateral lemniscus and play a role in auditory startle responses. In addition, the inferior colliculus and the auditory cortex project to the SC, where information is integrated with somatosensory inputs. These pathways are likely responsible for controlling orientation of the head, eyes, and body to sound.

HERE'S THE POINT

- Auditory receptors (hair cells), found in the organ of Corti in the inner ear, are activated through a series of events that begin when sound waves create movement of the tympanic membrane separating the outer and middle ear.
- Sound input is projected to brainstem nuclei, and from there information from both ears is projected to the superior olive. The receipt of bilateral auditory input allows for temporal interpretation of sound, and sound localization.
- Multisensory integration (somatosensory, visual, and auditory) takes place in the inferior colliculus and supports auditory attention.
- Projections of auditory input to the primary and secondary auditory cortices subserve a higher level of sound interpretation and complex mapping of the sound environment.
- Additional cortical projections, some to multisensory integration areas, are associated with such functions as sound interpretation, auditory attention, speech, reading, and writing.

The Visual System

Despite the pervasive nature of the tactile system and the importance of the vestibular system, we rely most heavily for day-to-day function on visual input. According to one neuroscience text, "It is vision that helps us to navigate in the world to judge the speed and distance of objects;

to identify food, members of other species, and familiar or unfamiliar members of our own species" (Zigmond, Bloom, Landic, Roberts, & Squire, 1999, p. 821); this global function has not changed. The visual system functions primarily as an edge, contrast, and movement detector. We perceive visual images best when they are still; therefore, our visual abilities depend, in part, on the vestibular-ocular reflex, which contributes to a stabilized visual field. The visual system itself can adjust to movement within the environment with the optokinetic reflex, which works with the vestibulo-ocular reflex to maintain a stable image on the retina. When disparity exists between visual and other sensory inputs—for instance, when we sit in a still car while the car-wash apparatus moves forward and backward over the surface—we get the visual impression that the car is moving, although vestibular and proprioceptive inputs tell us otherwise. Nonetheless, we believe the visual system and are likely to press on the brake pedal to stop us from "moving."

Visual processing involves at least three parallel pathways carrying information that must be integrated. Next, we will present a greatly simplified examination of structures and mechanisms underlying vision, beginning with a description of receptors, transduction, and visual pathways. We close with a brief consideration of function. Keep in mind that, within the visual system, more than any other sensory system, the whole is much greater than a mere summing of the parts.

Receptors and Transduction

Vision receptors are specialized cells located in the neural retina at the back of the eye. These **photoreceptors,** the rods and cones, transduce light energy into electrical energy that can be transmitted to the CNS (Fig. 4-25). Cones are responsible for day vision and rods for night vision. Cones mediate color vision and provide higher acuity than do rods, which are highly light sensitive and able to amplify light signals to enable vision in dim light. Although cone pathways are not convergent, maintaining a high degree of spatial resolution, rod pathways converge extensively (which further increases the ability to see in dim light by summing light input), which decreases the resolution capability of these receptors. In addition, rod cells respond slowly, which adds to their ability to sum dim light, allowing us to see in low-light conditions. On the other hand, cones respond rapidly, which allows us to see quick flashes of light.

Cone cells are of three types, each responding to a different spectrum of color: red, green, and blue. Differentiation of other colors depends on differential transmission of information from these three receptors. In contrast, rod cells are achromatic—that is, they respond to all wavelengths of light, but they do not allow for discrimination of color. In the center of the retina is an area called the **fovea.** In this region, light more readily reaches the receptor cells, and acuity is enhanced. There are no rods in the fovea, only a dense concentration of cones.

Transduction of light energy into the electrical signal needed to get information from receptor cells into the CNS is a complicated process. However, a brief look at this process helps us compare activity in this sensory system with that in others. The process of changing light energy into a neural signal begins with the rod and cone cells. These cells maintain tonic activity and transmit information to the CNS in an ongoing manner through neurotransmitter release. With a change in light or the detection of an edge or movement, a change in tonic activity occurs, either increasing or decreasing the amount of neurotransmitter released, and subsequently altering the ongoing signal to the CNS. Because of the complexity of the retina, a great deal of processing occurs in this neural structure before the time when information is transmitted over the optic nerve to the CNS.

Retina

The retina (Fig. 4-25) has 10 layers. The outer layer consists of the pigment epithelium. The neural retina forms the remaining nine layers. Light must travel through the outermost eight layers of the retina before falling on the receptor cells. Light hits the layers in this order:

1. Inner limiting membrane
2. Ganglion cell layer
3. Inner plexiform (synapses between ganglion, bipolar, and amacrine cells)
4. Inner nuclear layer (bipolar, amacrine, and horizontal cell bodies)
5. Outer plexiform layer (synapses between bipolar, horizontal, and receptor cells)

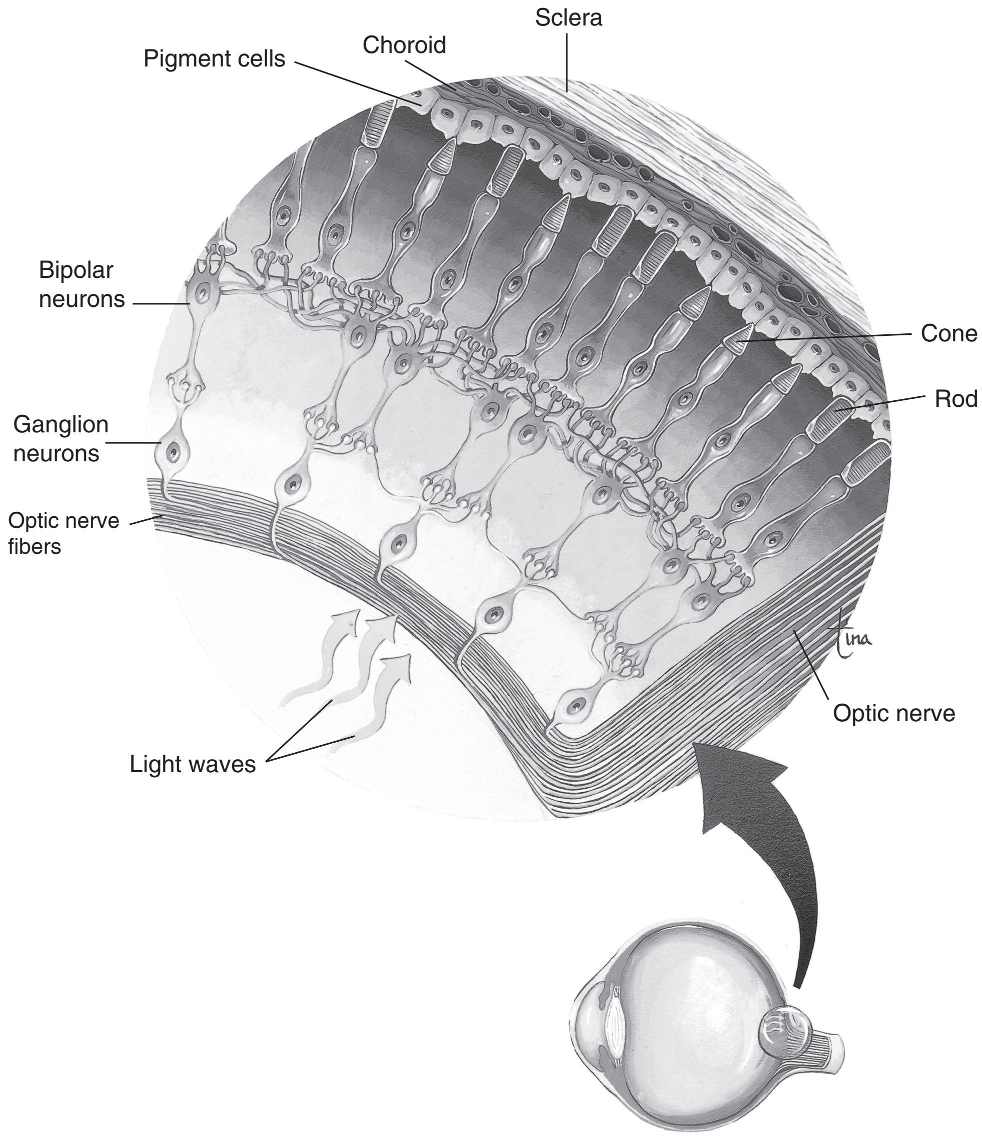

FIGURE 4-25 The retina consists of 10 cell layers, not all shown here. The photoreceptors (rods for low light vision and cones for color and detail vision) are located in the final cell layer. Shown in this figure are two other cell types in the retina, bipolar and ganglion cells. Ganglion cell axons form the optic nerve.

6. Outer nuclear layer (cell bodies for receptor cells)
7. Outer limiting membrane
8. Receptor layers (light sensitive receptor cell processes)
9. Pigment epithelium

Receptor cells (rods and cones) synapse onto bipolar cells found in the inner nuclear layer and from there connect with ganglion cells (Fig. 4-25), the axons of which form the optic nerve. The optic nerve projects to the lateral geniculate nucleus (LGN) of the thalamus and the SC, termed the "pretectal area" in Figure 4-26. Intervening in this process are interneurons known as **horizontal** and **amacrine cells,** also found in the inner nuclear layer. Although the receptor cells activate bipolar cells, the horizontal and amacrine cells exert an inhibitory influence on receptor, bipolar, and ganglion cells. The inhibition from horizontal cells is an example of lateral inhibition and serves to sharpen the edges

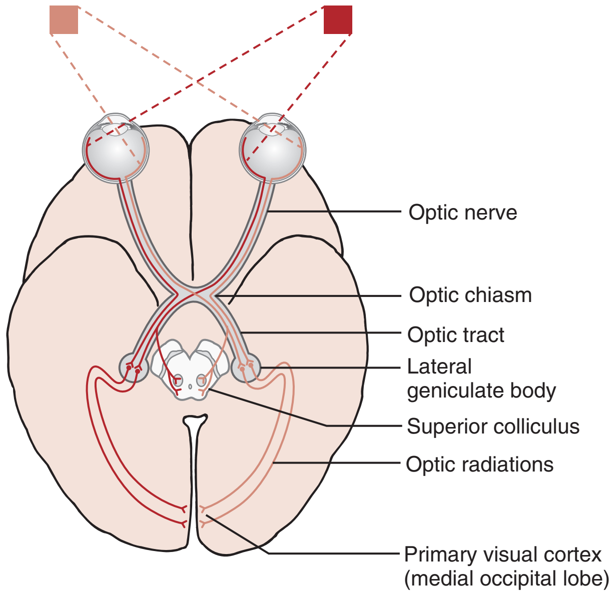

FIGURE 4-26 Visual information from the retina is transmitted by the ganglion cells in an organizational manner based on visual field. Fibers from the temporal half of the left retina join with fibers from the nasal half of the right retina, forming the left optic tract and projecting to the left thalamus. Similarly, left nasal and right temporal retinal fibers join to form the right optic tract and project to the right thalamus. This arrangement provides the brain with information about left and right visual space, respectively. In the thalamus, the lateral geniculate nuclei receive visual information, and project this on to the primary visual cortex, area 17. A secondary visual pathway involves optic tract fibers projecting to the superior colliculus.

of receptive fields, allowing for great accuracy in the information that travels to the CNS. Although bipolar cells work in a different manner, they also serve to sharpen the edges of visual images.

Ganglion cells can be grouped in two ways. First, ganglion cells can be categorized by characteristics of the receptive field associated with the receptor cells. Using this approach, one class of ganglion cell is activated by light directed at the center of its receptor field (on-center); another is turned off by light directed at the center of its receptor field (off-center). Forming two parallel routes to the CNS, the on-center and off-center information affords the ability to detect contrast in the visual image.

A second means of categorizing ganglion cells is based on size, connectivity, and properties; each category will include on- and off-center cells. Table 4-2 compares the various characteristics of the magnocellular and parvocellular cells.

Understanding our visual world, then, is not dependent solely on the absolute amount of light available; we use light and dark contrast, as well as edge detection and movement, for much of this information. The bottom line with this highly complex circuitry is that a great deal of information about contrast, color, form, and movement in the visual environment is processed before information reaches the CNS.

Central Connections

Gangliar projections form the optic nerve. As can be traced in Figure 4-25, fibers from the nasal region of the retina cross at the optic chiasm and join with fibers from the temporal retina of the opposite eye to form the optic tract, which projects primarily to the LGN of the thalamus. This is the first of the three processing pathways for visual information that we will discuss. The arrangement of fibers projecting to the LGN allows each hemisphere to receive visual information from the contralateral half of the visual world.

A detailed organization of fibers within the optic nerve continues into the optic tract and then is projected into the LGN. As with the tactile system, the representation within the LGN

TABLE 4-2 Differentiating between Magnocellular and Parvocellular Cells

	MAGNOCELLULAR ("WHERE")	PARVOCELLULAR ("WHAT")
Size of receptor field	Large	Small
Conduction of information	Rapid	Slower
Sensitive to	Contrast, even when it is low	Color; low contrast sensitivity
Response	Brief	Sustained
Main focus	General features of objects and object movement	Finer details of vision, spatial orientation, including form and color
Area of projection in LGN	Ventral layers 1 and 2	Dorsal layers 3 to 6

Liu, C.-S. J., Bryan, R. N., Miki, A., Woo, J. H., Liu, G. T., & Elliot, M. A. (2006). Magnocellular and parvocellular visual pathways have different blood oxygen level–dependent signal time courses in human primary visual cortex. *American Journal of Neuroradiology, 27,* 1628–1634.

reflects the size of the receptor field in the periphery. Thus, the fovea, which has the greatest number of receptor cells and the smallest receptor fields, has the greatest area of representation in the LGN.

Information from the LGN is projected to the ipsilateral primary visual cortex, or area 17 (Fig. 4-7). Here magnocellular and parvocellular pathways maintain their integrity, giving information about the "what" and "where" of visual images. Cells in the primary visual cortex are sensitive to the outline of an object but not to its interior. They respond to the specific position of an object as well as its axis or orientation. This is why the visual system is sometimes referred to as a **contrast** or **edge detector.**

The organization of the visual cortex is highly complex. Cells there form columns; neurons within a single column respond to a single axis or orientation. The columns are interrupted by what have been called **blob regions** of cells that are sensitive to color rather than axis. A third level of organization within this cortical region is a system of ocular dominance columns. These columns receive input from either the left or right eye, and they alternate at regular intervals, leading to binocular vision.

Visual perception depends on projections beyond area 17. Parvocellular pathway projections run from area 17 to area 19 and then to the inferior temporal region, where form and color are perceived. Projections to the inferior temporal cortex result in interpretations of the "what" of a visual image. This area of the brain is also associated with face and shape recognition.

Perception of motion has its origins in the responsivity of magnocellular ganglion cells in the retina and their projections to the LGN, area 17, area 18, and the middle or superior temporal area. Visual signals, then, project to the visual-motor area of the parietal lobe. This pathway carries information pertaining to the interpretation of speed and direction of object motion and assists in determining where objects are.

The second visual pathway begins with fibers from the optic tract projecting to the SC. Cells here have large receptive fields and, as such, do not interpret the specifics of the visual world. Instead, these cells respond to horizontal movement within the visual field. Other inputs to the SC come from the visual cortex and the spinotectal pathway, the latter of which carries somatosensory information from both the spinal cord and the medulla. Projections from the SC include those to the thalamus and others to the spinal cord via the tectospinal pathway. Other fibers are sent to the oculomotor nuclei. Thus, the SC plays a role in the visual coordination of posture and the control of eye movements.

The smallest visual pathway is called the **accessory optic tract.** Projections from the optic tract are sent to small (i.e., accessory) nuclei around the oculomotor nucleus, the medial vestibular nucleus, the LGN, and other regions of the thalamus. The efferent processes from these regions project largely to the inferior olive, which sends projections to the vestibular component of the cerebellum. With these connections, the accessory optic tract plays a role in oculomotor adaptation.

Visual Experience Counts

Development of skills within the visual system is dependent on experiences, both prenatally and postnatally. Cooperation and competition of axons from the same and opposite eye, respectively, are critical to the postnatal formation of ocular dominance columns and, thus, depth perception and binocular vision. Early studies of visual deprivation, conducted by temporarily closing one eye at birth and then allowing both eyes to see after a period of time, show that deprivation during critical postnatal periods results in blindness in the sutured eye even once it was opened (Hubel & Weisel, 1965). The blindness was reversible only if closure was short-lived (Hubel, Weisel, & LeVay, 1977). For instance, when congenital cataracts are present, it is critical to remove them very early. Robb and colleagues (1987) reported that the critical period to reverse deprivation amblyopia (or "lazy eye"), and achieve adequate acuity, involved removing cataracts before the age of 17 months. Kandel and colleagues (2013) indicated that cataracts not removed until 10 or more years of age lead to a permanent impairment of form perception, although color perception remains intact. Other incidences and studies of vision deprivation support this finding. Because of its impact on the connections among cortical cells, experience is critical to the development of normal visual perception. We present more detailed information on visual-spatial components of visual perception in Chapter 7 (Sensory Discrimination Functions and Disorders).

HERE'S THE POINT

- Vision is our dominant sensory system; it is responsible for edge, contrast, color, and movement detection.
- Changes in light in the environment activate the receptors (rods and cones, found in the retina), and a great deal of sensory processing takes place in the retina itself, before neural signals are sent to the brain.
- Ganglion fibers from the retina form the optic nerve and project to the LGN of the thalamus; different kinds of ganglion cells project to different layers of the LGN. This arrangement contributes to our understanding of "where" (magnocellular ganglion cells) and "what" (parvocellular ganglion cells) is in our visual environment.
- "Where" and "what" information is projected from the LGN to the visual cortex, where a complex organization of fibers and cells provides us with binocular vision and allows for interpretation of object orientation and color.
- Object identification information (supporting our interpretation of "what") reaches the inferior temporal lobe after passing through the visual cortex, providing us with our perception of object form and color; information related to perception of object movement is sent to middle and superior temporal lobes as well as regions of the parietal lobe.
- The role of the visual system in postural control and eye movements is a function of projections to the SC from the retina, visual cortex, and spinotectal pathways and from the SC to the thalamus and spinal cord.
- Our ability to accurately interpret visual input is experience dependent, and experiences must take place within time-sensitive windows for optimal function.

Gustation and Olfaction

The last two sensory systems we will look at are chemoreceptive systems, responding to chemicals in their specialized environments. They are the oldest and considered the most primitive of our sensory systems, in that they can be found pervasively throughout evolution. Here we will address gustation and olfaction. However, it is important to note that many of the interoceptors, addressed earlier, fall into the chemoreceptor functional category, as do some nerve endings in the skin and mucous membranes. We will address the neuroscience of gustation (taste) and olfaction (smell) individually because each system has unique properties. Functionally these two systems are closely linked; as such, we end this section by looking at the relationship of taste and smell to disorders related to the functional tasks of eating and feeding.

Taste and Taste Receptors

Taste is a mechanism by which we can distinguish between nutritious and noxious substances in the mouth. It is generally agreed that we are

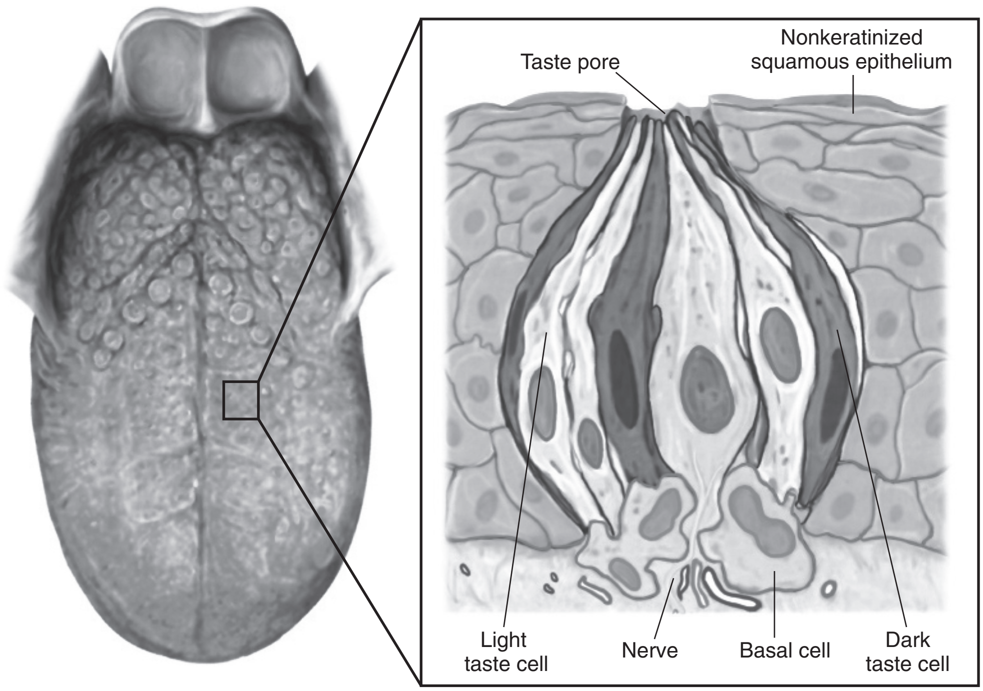

FIGURE 4-27 Taste cells are located on taste buds, here shown from the tongue. The taste pore is the opening to the taste bud. Two different taste cells are shown in this figure, along with the basal cells. At the base of the taste bud is the nerve fiber that will conduct information about taste to the brain. *From Eagle, S, et al. (2009).* The Professional Medical Assistant. *Philadelphia, PA: F.A. Davis Company: p. 540; with permission.*

born to find sweet tastes pleasant and bitter tastes noxious, at least initially. Mothers' milk is sweet, and we are driven to seek this. Many poisons carry a bitter taste, hence our natural tendency to reject bitter substances. Experience plays a role here, and we can become accustomed to bitter tastes, as drinkers of coffee and beer well know.

Taste is detected by taste cells, located on taste buds, which are themselves located on papillae on the tongue, soft palate, pharynx, and upper part of the esophagus (Fig. 4-27). Most of us have between 2,000 and 5,000 taste buds, each housing 50 to 150 taste cells. Each taste cell responds best to one of five specific tastes (sweet, sour, salty, bitter, and umami or savory), and papillae tend to be most sensitive to a single taste. Thus, we often see the tongue "mapped" for taste with sweet on the tongue tip, salty on either side of sweet, sour on the sides just posterior to salty, and bitter at the base of the tongue. However, when tastes are presented at higher concentrations, cells demonstrate less selectivity for a single taste. The chemicals that give food and beverages taste interact with taste cells, where transduction into a neural signal takes place. Information related to what we are tasting, its concentration and qualities, is coded by the taste cells and transmitted over sensory neurons to the CNS. We have the capacity to detect many different flavors, far more than the basic five identified here. This capacity is the result of the complex chemical makeup of foods and beverages activating various combinations of taste cells to varying degrees. Coding then is a crucial aspect of our broad-spectrum ability to taste. Importantly, smell also plays a role in our ability to detect flavors, as does the way a substance feels (texture, temperature, pain) in the mouth.

Taste Pathways

Taste afferents are divided among branches of three cranial nerves: facial (VII), glossopharyngeal (IX), and vagus (X). Afferents from all the nerves enter the medulla and project to

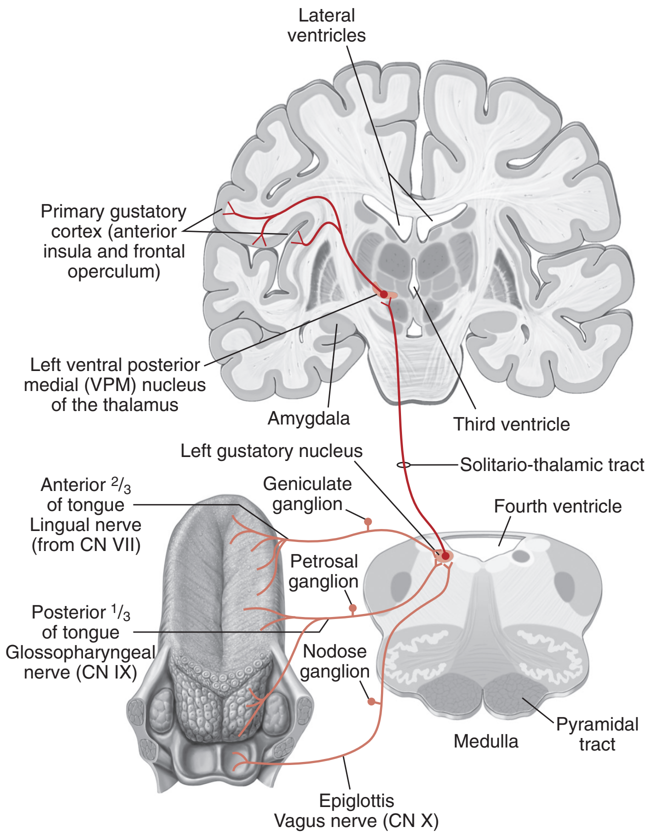

FIGURE 4-28 Taste sensation is carried by the facial, glossopharyngeal, and vagus nerves to a region of the solitary nucleus called the gustatory nucleus in the medulla. From here taste is projected to the ventral posterior medial thalamic nucleus and from there to the primary gustatory cortex in the insula.

a region of the solitary nucleus, known as the gustatory nucleus. The solitary nucleus also receives sensory input from the gut, and interneurons connect the gut and taste areas, providing a functional link between visceral and taste inputs. Information from the gustatory nucleus is projected to the VPM nucleus of the thalamus, the same nucleus that receives touch and proprioceptive input from the face by way of the trigeminothalamic pathway discussed earlier. From the VPM, taste information is projected to the primary gustatory cortex on the insula (Fig. 4-28), to a region of the frontal lobe called the operculum, and to a multisensory region of the orbitofrontal cortex. It is in the orbitofrontal cortex where taste is integrated with input about a food's smell, appearance, and texture. Taste information from the gustatory nucleus also projects to, and receives input from, the hypothalamus and the amygdala. Cortical projections are linked with our awareness of taste; projections to the hypothalamus and amygdala are associated with the affective aspects of taste, what we like and do not like, and our motivations around eating. Finally, there are projections to regions of the medulla that mediate basic physiological functions and play a role in swallowing, gag and vomit, the production of saliva, digestion, and respiration. Taste, then, is a multisensory process, involving integration at many levels.

Smell and Smell Receptors

Detection of smell involves the chemical processing of **odorants,** airborne chemical stimuli. According to Bear and colleagues (2015), of the thousands of smells that we can perceive, only about 20% are actually pleasant, suggesting that this system serves an important protective

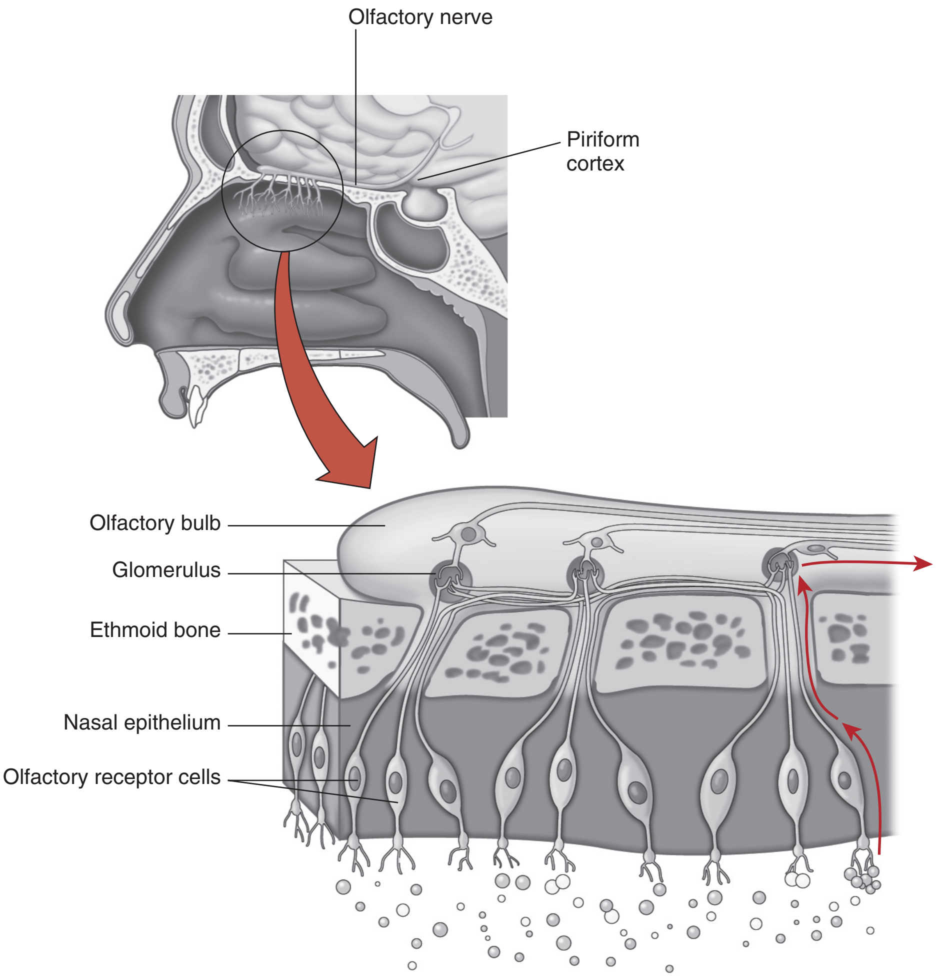

FIGURE 4-29 Smell is detected by olfactory cells in the nasal epithelium. Fibers from these receptors enter the olfactory bulb. From here, fibers form the lateral olfactory tract carrying information to the piriform cortex.

function, warning of dangers in the environment through detection of noxious odors. Smell receptors are located in the **olfactory epithelium,** a layer of receptor cells lining the nose (Fig. 4-29). This epithelium is coated by a thin layer of mucus, and odorants dissolve in the mucus and are concentrated there, enabling them to interact with the receptor cells. Part of this process involves the presence of receptor proteins in the mucus, which bind the odorants; our ability to smell a variety of odors comes from the existence of a large number of odorant-receptor proteins; humans have about 350. Interestingly, humans have relatively thin olfactory epithelia and, as such, limited smell acuity when compared with other animals. As was the case for taste, our ability to detect the wide array of environmental and personal odors comes from activating several receptor cells, which themselves are more or less sensitive to specific odorants, and the resultant coding of information that is sent to the CNS for interpretation. Olfactory receptor cells are somewhat more sensitive to some smells than others, but they do not show specificity for a single smell or group of smells. This means that interpretation of smell stimuli relies on CNS structures.

Smell Pathways

Axons from receptor cells travel through a thin bony structure called the **cribriform plate,** form the olfactory nerve (cranial nerve I), and project to the **olfactory bulb** as individual fibers (Fig. 4-29). Because the fibers do not coalesce into a larger nerve, they tend to be very fragile and easily injured or sheared by a blow to the head. This helps explain the frequency of the loss of smell in incidences of brain injury. In the olfactory bulb, the organization of structures provides a well-organized map of odor; further odor discrimination requires additional central processing. From the olfactory bulb, the lateral olfactory tract carries smell input to the olfactory or piriform cortex (Fig. 4-29). This makes the olfactory system unique from other sensory systems; it does not *first* project to the thalamus, instead going directly to a region of the cortex. Fibers from the piriform cortex do project to the thalamus and on to the prefrontal cortex. There is specific mapping of odorant information within the olfactory bulb, and the organization here is thought to underlie our ability to interpret and identify smell with input from the prefrontal cortex. Additionally, fibers from the lateral olfactory tract carry information to the amygdala and the entorhinal cortex, and onto the prefrontal cortex. The entorhinal pathway also projects to the hippocampus. These limbic system projections are associated with the affective aspects of smell as well as the close link behaviorally between smell and emotion. The medial olfactory tract connects smell to other basal forebrain structures; these connections mediate the autonomic responses to smell input.

Clinical Links to Taste or Smell Sensitivity Differences

Of interest related to the systems of taste and smell and the integration and use of sensation, is the potential link between eating and feeding difficulties and disorders and sensory modulation concerns. Eating and feeding disorders represent a broad group of concerns, encompassing children with and without additional diagnoses. Here we will look briefly at sensory concerns related to food selectivity, non-organic failure to thrive, eating concerns associated with ASD, and sensory issues related to obesity.

"Picky eating" is a concern that has no commonly accepted description but generally is thought to encompass food refusal, **food neophobia,** limited variety in food choice, and, often, other atypical eating behaviors (Cano et al., 2016; Kerzner et al., 2015). Picky eating is not infrequently reported in young children who are otherwise typical, and it is seen as either not of immediate concern or on the mild end of a continuum of eating disorders; many children pass through a picky eating stage and require no intervention. Multiple child factors, parent factors, and child-parent interaction factors appear to be at the core of picky eating (for review, see Cano, Hoek, & Bryant-Waugh, 2015). Factors related to both child and "feeder" behaviors have been linked to sensory processing differences in children with an array of feeding problems (Davis et al., 2013). Relative to child factors, recent work indicated that food texture contributes the most to picky eating (Werthmann et al., 2015). Additionally, picky eating in some young children is related to tactile overresponsivity (Nederkoorn, Jansen, & Havermans, 2015; Smith, Roux, Naidoo, & Venter, 2005), and food neophobia is linked with oral sensory sensitivity (Johnson, Davies, Boles, Gavin, & Bellows, 2015). Interestingly, Nederkoorn and colleagues identified food texture and the anticipation of how the food will feel in our mouths as a major issue, whereas Smith and colleagues indicated foods were refused because of smell and temperature. A relationship between feeding problems and sensory modulation was also suggested by Boquin, Moskowitz, Donovan, and Lee (2014). Taking a broad view on the introduction of new fruits and vegetables to young children, not necessarily identified as having either picky eating or tactile defensiveness, Dazeley and Houston-Price (2015) found that exploring the sensory qualities of new foods outside of mealtime resulted in greater willingness to taste and touch the foods. Such an approach, using playful sensory-based opportunities, is consistent with a core feature of SI.

Although limited, there is some indication that children with non-organic failure to thrive (NOFT) may have concomitant overresponsiveness to sensory input. Yi, Joung, Choe, Kim, and Kwon (2015) found that overresponsiveness in tactile, vestibular, and oral domains was more common in toddlers with NOFT than in a control group. They also found that these sensory concerns were related to delays in development and to maladaptive mealtime behavior.

HERE'S THE EVIDENCE

Food neophobia is a term applied when individuals are fearful of trying new foods. Although it is often considered a behavioral issue related to feeding disorders, some investigators are beginning to link it to sensory sensitivities. As part of a larger and ongoing study of obesity, Johnson, Davies, Boles, Gavin, and Bellows (2015) administered the Food Neophobia Scale and the Sensory Profile to a relatively large group (n = 249) of preschool-aged children who were otherwise typically developing. The researchers also measured body mass index and food intake. Findings suggested, among other things, a significant relationship between oral sensory sensitivity and food neophobia, as well as among food neophobia, limited vegetable consumption, and limited dietary variety. Other considerations to explain limited dietary variety and food neophobia included socioeconomic status (SES) factors and ethnicity. The authors concluded that more research is needed to better understand the overall relationships among sensory-related behaviors, food neophobia, limited dietary variety, and other family and environmental variables.

Johnson, S. L., Davies, P. L., Boles, R. E., Gavin, W. J., & Bellows, L. L. (2015). Young children's food neophobia characteristics and sensory behaviors are related to their food intake. *Journal of Nutrition, 145*(11), 2610–2616.

ASD and Sensory Modulation Concerns

More significant than picky eating, children with ASD are frequently identified as having eating or feeding disorders. Although incidence is difficult to identify clearly, somewhat older studies indicate that 46% to 90% of children with ASD present with some form of eating disorder, often persistent food refusal, restricted variety in food, or food neophobia (Ledford & Gast, 2006; Twachtman-Reilly, Amaral, & Zebrowski, 2008). Although the underlying cause for these behaviors remains speculative, one suggested possibility is sensory sensitivities to characteristics of food discussed earlier in this section: taste, smell, texture, and temperature (Cermak, Curtin, & Bandini, 2010; Ledford & Gast, 2006; Marshall, Hill, Ziviani, & Dodrill, 2014; Nadon, Feldman, Dunn, & Gisel, 2011; Vissoker, Latzer, & Gal, 2015; Zobel-Lachiusa, Andrianopoulos, Mailloux, & Cermak, 2015). In fact, Paterson and Peck (2011) and Zobel-Lachiusa and colleagues (2015) identified a strong correlation between more problematic sensory behaviors and mealtime behavior concerns in children with ASD, and the researchers suggested that intervention directed toward ameliorating sensory sensitivities might improve quality of life for both the child and family. Interestingly, in looking at children with ASD and feeding disorders, and children without ASD but with feeding disorders considered "nonmedically complex," Marshall and colleagues found that both groups evidenced oral motor and oral hypersensitivity, implicating the sensory aspects of feeding disorders for a broader population. Further, extreme taste-smell sensitivity in children with ASD has been identified as a sensory subtype by Lane and colleagues (Lane, Dennis, & Geraghty, 2011; Lane, Molloy, & Bishop, 2014; Lane, Young, Baker, & Angley, 2010), and these investigators linked it to difficulties in social communication; they did not examine specific eating behaviors. It is important to note that sensory sensitivities are not the only consideration for children with ASD and feeding or eating disorders; Vissoker and colleagues (2015) indicated that these problems are multifactorial and may be linked to well-documented GI dysfunction in children with ASD.

Obesity and Sensory Modulation Concerns

Other investigations of taste or smell sensitivity have focused on the issue of obesity. Rather than the increased sensitivity reported for children with ASD, evidence indicates that taste sensitivity is reduced in children with obesity, particularly for salty, umami, and bitter tastes; sweetness intensity was rated lower by children with obesity (Overberg, Hummel, Krude, & Wiegand, 2012). The causes of these differences are multifaceted, but they include learning effects and exposure to new foods, as was the case with picky eating. Children can be classified as either "tasters" or "non-tasters," and research indicates that preschoolers categorized as "non-tasters" showed a higher incidence of obesity and a greater intake of high fat savory foods; in contrast, "tasters" prefer sweets (Keller et al., 2014; Markam, Banda, Singh, Chakravarthy, & Gupta, 2015). There may be a role to be played by occupational therapy in working with children with obesity and reduced sensitivity or poor sensory discrimination of taste, but this will take time to tease out.

HERE'S THE POINT

- Olfaction and gustation are separate systems neuroanatomically, but they are closely related functionally.
- Our ability to interpret the wide variety of tastes and smells in the environment depends on a complex coding and interpretation process in these systems, which begins with the receptors and continues through CNS connections.
- Eating and feeding disorders are an area of functional overlap between taste and smell, linked with over-responsivity; these disorders also frequently are linked to disorders of tactile modulation. A sensory integrative approach to intervention may be warranted.
- A large percentage of young children with no specific diagnosis are noted to be "picky eaters"; many of them will grow out of this behavior with no intervention.
- Children identified with NOFT and ASD often also show sensory sensitivities in conjunction with feeding and eating challenges.
- There is growing evidence that children with obesity may be classified as "non-tasters," potentially under-responsive to taste, or with poor taste discrimination.
- Sensory-based feeding concerns may be well served by occupational therapy to address concerns related to sensory over-responsivity.

Summary and Conclusions

The major sensory systems subserving SI theory are complex, and we have only scratched the surface in explaining their structure and function. Each system relies on receptors that respond to one primary form of input and on the transformation of this input into an electrochemical form that can be read by the CNS. Because all input to the CNS eventually takes the form of electrochemical signals, interpretation of specific input depends on the receptors, the specific pathways over which the information is sent, and characteristics of the input, including frequency and intensity of transmission. Across all systems, the processing of sensory input begins subcortically, and a great deal of processing takes place in the brainstem, regions of the midbrain, and the thalamus. Our ability to modulate sensation is subcortical; more detail on sensory modulation can be found in Chapter 6 (Sensory Modulation Functions and Disorders). Perception and discrimination, however, require the cortex. You will find more on sensory discrimination in Chapter 7 (Sensory Discrimination Functions and Disorders).

Integration of inputs takes place in a multitude of CNS locations and subserves a multitude of functions. Although we have looked at each system individually, many comments have been made throughout this chapter related to multisensory integration; none of these systems functions "in a vacuum." Touch and proprioception provide information necessary for the establishment of body scheme; proprioception, vision, and vestibular inputs are crucial for our ability to maintain upright posture and move our body in and through space. Touch and vision interact in the process of developing skills such as stereognosis, determining "what" an object is; sound and vision contribute to our ability to determine "where" people and things are in the environment. In this chapter, we focused on the use of sensation in allowing us to perceive the environment but alluded to the application of SI in the production of movement. This will be detailed in Chapter 5 (Praxis and Dyspraxia).

The complexity within and between sensory systems is difficult to capture in one short chapter; you have likely found it difficult to digest, especially if you are new to the neuroscience foundations for SI theory. In Table 4-3 and the appendix that follows, we provide key points regarding the structure, function, and interaction among these systems that you may find useful!

TABLE 4-3 Sensory Systems and Projections

PATHWAY	ORGANIZATION	FUNCTION	FIBERS CROSS . . .	FIRST SYNAPSE	SECOND SYNAPSE	THIRD-ORDER SYNAPSE	And Beyond . . .
DCML	Precise somatotopic organization throughout Little convergence Few relays	Transmit size, form, texture information Detect movement of touch on skin Convey spatial and temporal aspects of touch	Gracile and cuneate nuclei of medulla	Gracile and cuneate nuclei	VPL of thalamus Reticular formation	Primary and secondary somatic cortex Areas 5 and 7 of parietal lobe	
Anterolateral	Somatotopic, but less specific More convergence	Pain, crude touch, temperature, tickle, neutral warmth	Dorsal horn of the spinal cord	Dorsal horn of the spinal cord	VPL of the thalamus Reticular formation Periaqueductal gray Tectum Hypothalamus	Primary and secondary somatosensory cortex Other thalamic nuclei	
Trigeminothalamic	Somatotopic	Discriminative touch from face and mouth Pain, temperature, nondiscriminative touch	After synapsing in the pons and brainstem	Principal sensory nucleus of the trigeminal nerve Spinal nucleus of the trigeminal nerve	Ventral posterior medial nucleus of the thalamus	Primary somatosensory cortex	

Continued

TABLE 4-3 Sensory Systems and Projections—cont'd

PATHWAY	ORGANIZATION	FUNCTION	FIBERS CROSS . . .	FIRST SYNAPSE	SECOND SYNAPSE	THIRD-ORDER SYNAPSE	And Beyond . . .
Vestibular		Position and movement of the head in space Maintenance of balance Coordination of the eyes Fixation of the eyes as the body moves through space Detection of speed and direction of movement	After synapsing in the vestibular nuclei in the medulla and pons	Vestibular ganglion	Cerebellum Oculomotor nuclei Alpha and gamma motor neurons VPL of the thalamus	Areas 3 and 2v of the cortex	
Auditory	Tonotypic Amplitude tuning curve	Sound detection and localization	Spiral ganglion in ear	Ventral and dorsal cochlear nuclei	Superior olive Trapezoid body	Inferior colliculus Medial geniculate nucleus of thalamus	Auditory cortex Precentral gyrus
Visual	Cones: little convergence, high degree of spatial resolution Rods: significant convergence; high light sensitivity; low resolution Detailed organization of information carried throughout this system	Cones: day vision, color Rods: night vision	At optic chiasm	Bipolar cells in retina	Ganglion cells in retina	Superior colliculus Lateral geniculate nucleus of thalamus	Primary visual cortex

Where Can I Find More?

In developing the material in this chapter, many sources were tapped because no single neuroscience text does it all. Some emphasize function, some emphasize structure, others take a systems approach, and still others take a geographic approach. All have their place, and all answer somewhat different questions. Rather than reference each statement that appeared in the chapter, we credit several sources now as they provided essential background, detail, and guidance to the structural and functional material in this chapter.

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain* (4th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Haines, D. E. (2013). *Fundamental neuroscience for basic and clinical applications.* New York, NY: Churchill Livingstone.

Jessell, T. M., Kandel, E. R., & Schwartz, J. H. (2012). *Principles of neural science* (5th ed.). New York, NY: McGraw-Hill.

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth, A. J. (2013). *Principles of neural science* (5th ed.). New York, NY: McGraw-Hill Companies, Inc.

Kiernan, J., & Rajakumar, R. (2014). *Barr's the human nervous system: An anatomical viewpoint.* Philadelphia, PA: Lippincott Williams & Wilkins.

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2011). *Neuroscience* (5th ed.). Sunderland, MA: Sinauer Associates, Inc.

Siegel, A., & Sapru, H. N. (2013). *Essential neuroscience* (3rd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Squire, L., Berg, D., Bloom, F. E., duLac, S., Ghosh, A., & Spitzer, N. C. (2012). *Fundamental neuroscience* (4th ed.). Cambridge, MA: Academic Press.

At appropriate points within this chapter, we referenced sources that offer more limited input and particularly good explanations of specific constructs.

References

Abraira, V. E., & Ginty, D. D. (2013). The sensory neurons of touch. *Neuron, 79,* 618–639.

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Baloh, R., & Kerber, K. (2010). *Clinical neurophysiology of the vestibular system.* New York, NY: Oxford University Press.

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain* (4th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Blackwell, P. L. (2000). The influence of touch on child development: Implications for intervention. *Infants and Young Children, 13*(1), 25–39.

Boquin, M. M., Moskowitz, H. R., Donovan, S. M., & Lee, S. Y. (2014). Defining perceptions of picky eating obtained through focus groups and conjoint analysis. *Journal of Sensory Studies, 29*(2), 126–138. doi:10.1111/joss.12088

Cano, S. C., Hoek, H. W., & Bryant-Waugh, R. (2015). Picky eating: The current state of research. *Current Opinion in Psychiatry, 28,* 448–454.

Cano, S. C., Hoek, H. W., van Hoeken, D., de Barse, L. M., Jaddoe, V. W. V., Verhulst, F. C., & Tiemeier, H. (2016). Behavioral outcomes of picky eating in childhood: A prospective study in the general population. *Journal of Child Psychology and Psychiatry, 57*(11), 1239–1246.

Cermak, S. A., Curtin, C., & Bandini, L. G. (2010). Food selectivity and sensory sensitivity in children with autism spectrum disorders. *Journal of the American Dietetic Association, 110,* 238–246. doi:10.1016/j.jada.2009.10.032

Chen, H.-Y., Yang, H., Chi, H. J., & Chen, H. M. (2013). Physiological effects of deep touch pressure on anxiety alleviation: The weighted blanket approach. *Journal of Medical and Biological Engineering, 33*(5), 463–470.

Cohen, H. (1999). *Neuroscience for Rehabilitation* (2nd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Collier, C. (1985). *Emotional expression.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Coq, J. O., & Xerri, C. (1999). Tactile impoverishment and sensorimotor restriction deteriorate the forepaw cutaneous map in the primary somatosensory cortex of adult rats. *Experimental Brain Research, 129*(4), 518–531.

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews: Neuroscience, 3*(8), 655–666.

Craig, A. D. (2009). How do you feel now? The anterior insula and human awareness. *Nature Reviews: Neuroscience, 10*(1), 59–70.

Craig, A. D. (2015). *How do you feel? An interoceptive moment with your neurobiological self.* Princeton, NJ: Princeton University Press.

Crapse, T. B., & Sommer, M. A. (2008). Corollary discharge circuits in the primate brain. *Current Opinion in Neurobiology, 18,* 552–557.

Croker, C. A. (2013). *Motor learning and control for practitioners.* Scottsdale, AZ: Holcomb Hathaway Publishers, Inc.

Davis, A. M., Bruce, A. S., Khasawneh, R., Schulz, T., Fox, C., & Dunn, W. (2013). Sensory processing issues in young children presenting to an outpatient feeding clinic: A retrospective chart review. *Journal of Pediatric Gastroenterology and Nutrition, 56*(2), 156–160. doi:10.1097/MPG.0b013e3182736e19

Dazeley, P., & Houston-Price, C. (2015). Exposure to foods' non-taste sensory properties. A nursery intervention to increase children's willingness to try fruit and vegetables. *Appetite, 84,* 1–6.

Di Martino, A., Ross, K., Uddin, L. Q., Sklar, A. B., Castellanos, F. X., & Milham, M. P. (2009). Functional brain correlates of social and nonsocial processes in autism spectrum disorders: An activation likelihood estimation meta-analysis. *Biologic Psychiatry, 65*(1), 63–74.

Diamond, M. C., & Hopson, J. (1998). *Magic trees of the mind.* New York, NY: Dutton.

Dieterich, M., & Brandt, T. (2015). The bilateral central vestibular system: Its pathways, functions, and disorders. *Annals of the New York Academy of Sciences, 1343,* 10–26. doi:10.1111/nyas.12585

Edelson, S. M., Edelson, M. G., Kerr, D. C. R., & Grandin, T. (1999). Behavioral and physiological effects of deep pressure on children with autism: A pilot study evaluating the efficacy of Grandin's hug machine. *American Journal of Occupational Therapy, 53*(2), 145–152.

Elwin, M., Schröder, A., Ek, L., & Kjellin, L. (2012). Autobiographical accounts of sensing in Asperger syndrome and high-functioning autism. *Archives of Psychiatric Nursing, 26*(5), 420–429. doi:10.1016/j.apnu.2011.10.003

Ferrell, W. R., & Smith, A. (1988). Position sense at the proximal interphalangeal joint of the human index finger. *Journal of Physiology, 399,* 49–61.

Fiene, L., & Brownlow, C. (2015). Investigating interoception and body awareness in adults with and without autism spectrum disorder. *Autism Research, Online 25 March 2015.* doi:10.1002/aur.1486

Fisher, A. G. (1989). Objective assessment of the quality of response during two equilibrium tests. *Physical and Occupational Therapy in Pediatrics, 9*(3), 57–78.

Fisher, A. G., & Bundy, A. C. (1989). Vestibular stimulation in the treatment of postural and related disorders. In O. D. Payton, R. P. DiFabio, S. V. Paris, E. J. Prostas, & A. F. VanSant (Eds.), *Manual of physical therapy techniques* (pp. 239–258). New York, NY: Churchill Livingstone.

Fisher, A. G., Mixon, J., & Herman, R. (1986). The validity of the clinical diagnosis of vestibular dysfunction. *Occupational Therapy Journal of Research, 6,* 3–20.

Gilman, S., & Newman, S. W. (1992). *Essentials of clinical neuroanatomy and neurophysiology* (9th ed.). Philadelphia, PA: F.A. Davis.

Gokeler, A., Benjaminse, A., Hewett, T. E., Lephart, S. M., Engebretsen, L., Ageberg, E., . . . Dijkstra, P. U. (2011). Proprioceptive deficits after ACL injury: Are they clinically relevant? *British Journal of Sports Medicine, 46,* 180–192.

Goldberg, G. (1985). Supplementary motor area structure and function: Review and hypotheses. *Behavioral and Brain Sciences, 8,* 567–616.

Goldberg, J. M., Wilson, V. J., Cullen, K. E., Angelakik, D. E., Broussard, D. M., Buttner-Ennever, J. A., . . . Minor, L. B. (2012). *The vestibular system. A 6th sense*. New York, NY: Oxford University Press, Inc.

Goodwin, A. W., & Wheat, H. E. (2004). Sensory signals in neural populations underlying tactile perception and manipulation. *Annual Review of Neuroscience, 27,* 53–77. doi:10.1146/annurev.neuro.26.041002.131032

Haines, D. E. (2013). *Fundamental neuroscience for basic and clinical applications.* New York, NY: Churchill Livingstone.

Haron, M., & Henderson, A. (1985). Active and passive touch in developmentally dyspraxic and normal boys. *Occupational Therapy Journal of Research, 5,* 102–112.

Holt, J. C., Lysakowski, A., & Goldberg, J. M. (2011). The efferent vestibular system. In D. K. Ryugo, R. R. Fay, & A. N. Popper (Eds.), *Auditory and vestibular efferents* (pp. 135–186). New York, NY: Springer.

Hubel, D. H., & Weisel, T. N. (1965). Binocular interaction in striate cortex of kittens reared with artificial squint. *Journal of Neurophysiology, 28,* 1041–1059.

Hubel, D. H., Weisel, T. N., & LeVay, S. (1977). Plasticity of ocular dominance columns in monkey striate cortex. *Philosophical Transactions of the Royal Society of London, Series B. Biological Science, 278,* 377–409.

Jenkins, W. M., Merzenich, M. M., Ochs, M. T., Allard, T., & Guic-Robles, E. (1990). Functional reorganization of primary somatosensory cortex in adult owl monkeys after behaviorally controlled tactile stimulation. *Journal of Neurophysiology, 63,* 82–104.

Johansson, R. S., & Flanagan, J. R. (2009). Coding and use of tactile signals from the fingertips in object manipulation tasks. *Nature Reviews. Neuroscience, 10*(5), 345–359. doi:10.1038/nrn2621

Johnson, S. L., Davies, P. L., Boles, R. E., Gavin, W. J., & Bellows, L. L. (2015). Young children's food neophobia characteristics and sensory behaviors are related to their food intake. *Journal of Nutrition, 145*(11), 2610–2616.

Jones, L. A., & Smith, A. M. (2014). Tactile sensory system: Encoding from the periphery to the cortex. *Wiley Interdisciplinary Review Systems Biology and Medicine, 6*(3), 279–287.

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth, A. J. (2013).

Principles of neural science (5th ed.). New York, NY: McGraw-Hill Companies, Inc.

Keller, K. L., Olsen, A., Cravener, T. L., Bloom, R., Chung, W. K., Deng, L., . . . Meyermann, K. (2014). Bitter taste phenotype and body weight predict children's selection of sweet and savory foods at a palatable-test meal. *Appetite, 77C,* 113–121.

Kerzner, B., Milano, K., MacLean, W. C., Berall, G., Stuart, S., & Chatoor, I. (2015). A practical approach to classifying and managing feeding difficulties. *Pediatrics, 135*(2), 344–353. doi:10.1542/peds.2014-1630

Kirsch, V., Keeser, D., Hergenroeder, T., Erat, O., Ertl-Wagner, B., Brandt, T., & Dieterich, M. (2014). Structural and functional connectivity mapping of the vestibular circuitry from human brainstem to cortex. *Brain Structure and Function, 221*(3), 1291–1308.

Lane, A. E., Dennis, S. J., & Geraghty, M. E. (2011). Brief report: Further evidence of sensory subtypes in autism. *Journal of Autism and Developmental Disorders, 41*(6), 826–831. doi:10.1007/s10803-010-1103-y

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of children with autism spectrum disorder by sensory subtype: A case for sensory-based phenotypes. *Autism Research, 7*(3), 322–333. doi:10.1002/aur.1368

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders, 40*(1), 112–122. doi:10.1007/s10803-009-0840-2

Ledford, J. R., & Gast, D. L. (2006). Feeding problems in children with autism spectrum disorders: A review. *Focus on Autism and Other Developmental Disabilities, 21*(3), 153–166.

Liem, F., Hurschler, M. A., Jancke, L., & Meyer, M. (2014). On the planum temporale lateralization in suprasegmental speech perception: Evidence from a study investigating behavior, structure, and function. *Human Brain Mapping, 35,* 1779–1789.

Liu, C.-S.J., Bryan, R. N., Miki, A., Woo, J. H., Liu, G. T., & Elliot, M. A. (2006). Magnocellular and parvocellular visual pathways have different blood oxygen level–dependent signal time courses in human primary visual cortex. *American Journal of Neuroradiology, 27,* 1628–1634.

Markam, V., Banda, N. R., Singh, G., Chakravarthy, K., & Gupta, M. (2015). Does taste perception effect body mass index in preschool children? *Journal of Clinical and Diagnostic Research, 9*(12), ZC01–ZC04.

Marshall, J., Hill, R. J., Ziviani, J., & Dodrill, P. (2014). Features of feeding difficulty in children with autism spectrum disorder. *International Journal of Speech and Language Pathology, 16,* 51–58.

Matthews, P. B. C. (1988). Proprioceptors and their contribution to somatosensory mapping: Complex messages require complex processing. *Canadian Journal of Physiology and Pharmacology, 66,* 430–438.

McCloskey, D. I. (1985). Knowledge about muscular contractions. In E. V. Evarts, S. P. Wise, & B. Bousfield (Eds.), *The motor system in neurobiology* (pp. 149–153). New York, NY: Elsevier.

McCloskey, D. I., Cross, M. J., Honner, R., & Potter, E. K. (1983). Sensory effects of pulling and vibrating exposed tendons in man. *Brain, 106,* 21–37.

McHaffie, J. G., Fuentes-Santamaria, J. C., Alvarado, A. L. F. F., Gutierrez-Ospina, G., & Stein, B. E. (2012). Anatomical features of the intrinsic circuitry underlying multisensory integration in the superior colliculus. In B. E. Stein (Ed.), *The new handbook of multisensory processes* (pp. 31–48). Cambridge, MA: The MIT Press.

Moberg, E. (1983). The role of cutaneous afferents in position sense, kinaesthesia, and motor function of the hand. *Brain, 106,* 1–19.

Mogliner, A., Grossmann, J. A., Ribary, U., Joliot, M., Volkmann, J., Rapaport, D., . . . Llinas, R. R. (1993). Somatosensory cortical plasticity in adult humans revealed by magnetoencephalography. *Proceedings of the National Academy of Sciences, USA, 90,* 3593–3597.

Montagu, A. (1978). *Touching: The human significance of the skin.* New York, NY: Harper and Row.

Nadon, G., Feldman, D. E., Dunn, W., & Gisel, E. (2011). Association of sensory processing and eating problems in children with autism spectrum disorders. *Autism Research and Treatment,* Article ID 541926, 8 pages.

Nashner, L. M. (1982). Adaptation of human movement to altered environments. *Trends in Neuroscience, 5,* 351–361.

Nederkoorn, C., Jansen, A., & Havermans, R. C. (2015). Feel your food. The influence of tactile sensitivity on picky eating in children. *Appetite, 84,* 7–10. doi:10.1016/j.appet.2014.09.014

Overberg, J., Hummel, T., Krude, H., & Wiegand, S. (2012). Differences in taste sensitivity between obese and non-obese children and adolescents. *Archives of Diseases of Childhood, 97,* 1048–1052.

Paterson, H., & Peck, K. (2011). Sensory processing ability and eating behaviour in children with autism. *Journal of Human Nutrition and Dietetics, 24,* 301.

Proske, U., & Gandevia, S. C. (2012). The proprioceptive senses: Their roles in signaling body shape, body position and movement, and muscle force. *Physiologic Review, 92,* 1651–1697. doi:10.1152/physrev.00048.2011

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2011). *Neuroscience* (5th ed.). Cambridge, MA: Sinauer Associates, Inc.

Recanzone, G. H., Merzenich, M. M., & Jenkins, W. M. (1992). Frequency discrimination-training engaging a restricted skin surface results in an emergence of a cutaneous response zone in cortical area 3a. *Journal of Neurophysiology, 67*(5), 1057–1070.

Reynolds, S., Lane, S. J., & Mullen, B. (2015). Effects of deep pressure stimulation on physiological arousal. *American Journal of Occupational Therapy, 69*(3), 6903350010p1-6903350010p5. doi:10.5014/ajot.2015.015560

Rine, R. M., & Wiener-Vacher, S. (2013). Evaluation and treatment of vestibular dysfunction in children. *NeuroRehabilitation, 32*(3), 507–518.

Robb, R. M., Mayer, D. L., & Moore, B. D. (1987). Results of early treatment of unilateral congenital cataracts. *Journal of Pediatric Ophthalmology and Strabismus, 24,* 178–181.

Roberts, T. D. M. (1978). *Neurophysiology of postural mechanisms* (2nd ed.). Boston, MA: Butterworths.

Rose, M. F., Ahmad, K. A., Thaller, C., & Zoghbi, H. Y. (2009). Excitatory neurons of the proprioceptive, interoceptive, and arousal hindbrain networks share a developmental requirement for math. *Proceedings of the National Academy of Science, 106*(52), 22462–22467.

Sahley, T. L., & Musiek, F. E. (2015). *Basic fundamentals in hearing science.* San Diego, CA: Plural Publishing.

Schmidt, R., & Lee, T. (2011). *Motor control and learning. A behavioral emphasis* (5th ed.). Champaign, IL: Human Kinetics.

Sherrington, C. S. (1906). *The integrative action of the nervous system.* New Haven, CT: Yale University Press.

Siegel, A., & Sapru, H. N. (2013). *Essential neuroscience* (3rd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Siegel, A., Sapru, H. N., & Siegel, H. (2015). *Essential Neuroscience* (3rd ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Smith, A. M., Roux, S., Naidoo, N. T. R., & Venter, D. J. L. (2005). Food choices of tactile defensive children. *Nutrition, 21,* 14–19.

Soto, E., & Vega, R. (2010). Neuropharmacology of vestibular system disorders. *Current Neuropharmacology, 8*(1), 26–40.

Squire, L., Berg, D., Bloom, F. E., du Lac, S., Ghosh, A., & Spitzer, N. C. (2012). *Fundamental neuroscience* (4th ed.). Philadelphia, PA: Academic Press.

Tracey, D. J. (1985). Joint receptors and the control movement. In E. V. Evarts, S. P. Wise, & B. Bousfield (Eds.), *The motor system in neurobiology* (pp. 178–182). New York, NY: Elsevier.

Twachtman-Reilly, J., Amaral, S. C., & Zebrowski, P. P. (2008). Addressing feeding disorders in children on the autism spectrum in school-based settings: Physiological and behavioral issues. *Language, Speech, and Hearing Services in Schools, 39,* 261–272.

Uddin, L. Q., & Menon, V. (2009). The anterior insula in autism: Under-connected and under-examined. *Neuroscience and Biobehavioral Reviews, 33,* 1198–1203.

Vasa, R. A., Carroll, L. M., Nozzolillo, A. A., Mahajan, R., Mazurek, M. O., Bennett, A. E., . . . Bernal, M. P. (2014). A systematic review of treatments for anxiety in youth with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 44,* 3215–3229.

Vissoker, R. E., Latzer, Y., & Gal, E. (2015). Eating and feeding problems and gastrointestinal dysfunction in autism spectrum disorders. *Research in Autism Spectrum Disorders, 12,* 10–21.

Werthmann, J., Jansen, A., Havemans, R., Niederkoom, C., Kremers, S., & Roefs, A. (2015). Bits and pieces. Food texture influences food acceptance in young children. *Appetite, 84,* 81–87. doi:10.1016/j.appet.2014.09.025

Wilson, V. J., & Melvill Jones, G. (1979). *Mammalian vestibular physiology.* New York, NY: Plenum.

Yi, S.-H., Joung, Y.-S., Choe, Y. H., Kim, E.-H., & Kwon, J.-Y. (2015). Sensory processing difficulties in toddlers with nonorganic failure-to-thrive and feeding problems. *Journal of Pediatric Gastroenterology and Nutrition, 60*(6), 819–824.

Yu, T.-Y., Hinojosa, J., Howe, T.-H., & Voelbel, G. T. (2012). Contribution of tactile and kinesthetic perceptions to handwriting in Taiwanese children in first and second grade. *OTJR: Occupation, Participation, and Health, 32*(3), 87–94.

Zigmond, M. J., Bloom, F. E., Landic, S. C., Roberts, J. L., & Squire, L. R. (1999). *Fundamental neuroscience.* Boston, MA: Academic Press.

Zobel-Lachiusa, J., Andrianopoulos, M. V., Mailloux, Z., & Cermak, S. A. (2015). Sensory differences and mealtime behavior in children with autism. *American Journal of Occupational Therapy, 69*(2), 97–105. doi:10.5014/ajot.2015.016790

APPENDIX **4-1**

System Highlights

Somatosensory System

- Receptors are in the skin and around the joints, making this system very pervasive.
- Interpretation of input depends on the combination of receptors activated, receptor density, and receptor field size.
- Two major subdivisions carry information from the body to the CNS: the DCML and the AL systems.
- DCML:
  - Tactile discrimination, vibration, touch-pressure, proprioception, temporal and spatial aspects of a stimulus
  - Main projections: thalamus, S-I, S-II, areas 5, 7
- Proprioception:
  - Information travels within the DCML
  - Perception of joint and body movement, and position of body and body segments in space
  - Main sources: muscle spindles, skin mechanoreceptors, centrally generated motor commands
  - Proprioceptive and vestibular inputs are closely connected functionally, contributing to development of body scheme and postural responses, postural tone and equilibrium, and stabilization of head and eyes during movement
- AL:
  - Pain, temperature, light touch, tickle
  - Includes the following pathways: spinothalamic, spinoreticular, spinomesencephalic, spinohypothalamic
  - Main projections: thalamus, S-I, S-II; reticular formation, periaqueductal gray and midbrain tectum; hypothalamus (as suggested by pathway names)
- Trigeminothalamic pathway:
  - Carries all forms of somatosensory information from the face to the CNS
  - Main projections: thalamus, S-I
- Somatosensation has a pervasive influence on occupational performance because of the wide distribution of receptors and widespread projections within the CNS.
- There is considerable overlap among projections of two major subdivisions with many potential points of interaction.

Vestibular System

- Receptors are hair cells in two structures within inner ear:
  - Otolith organs: respond to linear movement and gravity, head tilt in any direction
  - Semicircular canals: respond to angular movement of the head; respond best to transient, quick movements
- Activity of receptors provides tonic input to the CNS about the movement and position of the head in space.
- Vestibular nerve fibers project to vestibular nuclei in the brainstem and from there to:
  - Cerebellum: reciprocal connections for ongoing control of eye and head movements and posture
  - Oculomotor nuclei: serving to fix the eyes as the head and body move
    - Source of vestibular-ocular reflex and nystagmus
  - Spinal cord: influences on muscle tone and ongoing postural adjustments
  - Thalamus and cortex: integration with somatosensory inputs; play a role in perception of motion and spatial orientation

Auditory System

- Hair cell receptors function similar to those in the vestibular system.
- Sound energy must be changed to vibration and to fluid movement energy to activate receptors.
- Two major auditory pathways:
  - Core pathway
    - Fastest and most direct
    - Maintains precise organization throughout course
    - Transmits sound frequency
  - Belt pathway
    - Less well organized
    - Surrounds core pathway
    - Transmits information relative to timing and intensity of sound input
    - Important in bilateral interaction of sound
- Main auditory projections of both core and belt pathways from cochlear nuclei:
  - Most direct route: axons from the lateral lemniscus project to inferior colliculus
  - Ipsilateral and contralateral projections to the superior olivary complex and onto the inferior colliculus
  - Fibers forming the trapezoid body project to the superior olivary complex
- From the inferior colliculus, most fibers project to the medial geniculate nucleus (MGN) of the thalamus and from there to the auditory cortex, areas 41 and 42, and auditory association cortex, area 22.
- Other MGN projections go to the limbic system and temporal and parietal lobes; these are thought to play a role in arousal and attention.
- Auditory inputs are integrated with somatosensory inputs in the SC to play a role in controlling orientation of the head, eyes, and body to sound.

Visual System

- Receptors are rods and cones, responding to night and day vision, respectively.
- Rods are slow-responding receptors, with the capacity to sum input even in dim light.
- Cones rapidly respond to changes in light and provide color vision.
- The retina is a complex multilayer structure, and a great deal of processing goes on here before information is transmitted to the CNS.
- Three pathways to the CNS:
  - Lateral geniculate pathway
    - Has parvocellular (P) and magnocellular (M) divisions processing information related to the *what* and *where* of an object, respectively
    - Projects to the visual cortex (areas 17 and 19) and on to the inferior and superior temporal cortex for additional processing and recognition of faces, shapes, and motion
  - SC pathway
    - Responses to horizontal movement in visual field
    - Integration with somatosensory input from thalamus
    - Projects to thalamus, spinal cord, and oculomotor nuclei to play a role in coordination of posture and eye movements
  - Accessory optic tract pathway
    - Optic tract projections to accessory nuclei around the oculomotor nucleus, medial vestibular nucleus, and thalamus
    - Projects to inferior olive and on to cerebellum
    - Plays a role in oculomotor adaptation

CHAPTER 5

Praxis and Dyspraxia

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Etiology of developmental dyspraxia clearly is not understood, perhaps because there is little agreement as to what it is and how it can be assessed.

—Sugden & Keogh (1990, p. 133)

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe terminology and explain diagnoses related to disorders of praxis.
- ✔ Describe the role of sensation and sensory integration (SI) theory in understanding praxis and dyspraxia.
- ✔ Discuss and compare difficulties associated with ideation, somatodyspraxia, and bilateral integration and sequencing.
- ✔ Describe neuroanatomic mechanisms hypothesized to underlie praxis.
- ✔ Explain the impact of disorders of praxis on development and occupational performance and daily functioning.
- ✔ Become familiar with evidence-based literature related to sensory-based disorders of praxis.

Introduction

Ayres (1985) defined praxis as "the neurological process by which cognition directs motor action; motor or action planning is that intermediary process that bridges ideation and motor execution to enable adaptive interactions with the physical world" (p. 71). Thus, praxis pertains to more than just physical acts of interacting with the environment, it encompasses the process of conceptualizing and planning those motor acts. It is a process that requires knowledge of actions and of objects, motivation, and intention on the part of the person.

Researchers' interest in praxis arose from investigations with adults who had sustained traumatic brain injury, primarily to the left frontal or parietal lobes, resulting in the inability to perform voluntary or goal-directed actions (Foundas, 2013). This disorder, known as **apraxia,** interfered with the ability to perform learned actions and impeded the ability to use gestures for communication in the absence of paralysis, sensory loss, or disturbance of muscle tone. In contrast, the term **dyspraxia** is used to describe motor planning deficits that are developmental rather than acquired. Because difficulties with motor actions are observable, dyspraxia might be assumed to be a problem of motor execution. Ayres (1985), however, suggested that dyspraxia was primarily a problem of *organizing the plan* necessary for purposeful behavior. Ayres (1972b, 1985) believed that the ability to process and integrate sensation formed the basis for the development of body scheme. This, in turn, provided a foundation for the conceptualizations needed for motor planning. Thus, occupational therapists who view praxis from a sensory integrative perspective are concerned with individuals' sensory processing and conceptual abilities (Ayres, 1985; Cermak, 2011).

Praxis and dyspraxia are complex concepts, and the terminology associated with them can be confusing. The lack of agreement as to what praxis is and how it can be assessed continues to exist today (Steinman, Mostofsky, & Denckla, 2010;

Sugden, Kirby, & Dunford, 2008; Vaivre-Douret, 2014). The term *dyspraxia* is sometimes applied to children with **developmental coordination disorder (DCD),** a term from the *Diagnostic and Statistical Manual of Mental Disorders (DSM)* referring to a neurodevelopmental disorder in which motor performance "is substantially below expected levels, given the person's chronologic age and previous opportunities for skill acquisition" (American Psychiatric Association, 2013). This condition may share characteristics common to the concept of dyspraxia. Some use the terms *dyspraxia* and *DCD* synonymously (Vaivre-Douret, 2014), whereas others see dyspraxia as a symptom and not a diagnosis (Steinman et al., 2010). The poor motor performance may manifest as coordination problems, poor balance, clumsiness, dropping or bumping into things, or in the acquisition of basic motor skills (e.g., catching, throwing, kicking, running, jumping, hopping, cutting, coloring, printing, writing). These motor problems must interfere significantly with activities of daily living (ADLs) or academic achievement (American Psychiatric Association, 2013). The term *dyspraxia* refers to developmentally based practic disorders with a variety of etiologies, whereas somatodyspraxia is identified specifically as a practic deficit having its foundations in impairments in somatosensory processing and related deficits in body schema. This distinction regarding the sensory foundations of the motor performance problem is not typically recognized in much of the literature on DCD. In this chapter, research related to children with DCD will be examined along with children with dyspraxia, as children with these diagnoses are often one and the same. Furthermore, they are often both seen by occupational therapists using the sensory integration (SI) frame of reference to address similar or the same kinds of deficits.

Purpose and Scope

In this chapter, sensory integrative-based practic dysfunction, frequently referred to as *dyspraxia* by occupational and physical therapists, is described as being manifested as difficulties in generating ideas for planning and organizing movement. Specifically, the characteristics of praxis difficulties are described in terms of deficits in ideation, somatodyspraxia, and bilateral integration and sequencing (BIS). Somatodyspraxia, BIS, and visuopraxis are recognized subtypes of dyspraxia that are hypothesized to reflect aspects of practic deficit distinguished primarily by their underlying sensory foundations. Deficits specifically in the ideational component of praxis as a possible additional subtype are discussed. Sensory integrative-based disorders of praxis have been identified traditionally through administration of the Sensory Integration and Praxis Tests (SIPT; Ayres, 1989). This chapter discusses the importance of assessment for determining different types of dyspraxia. This chapter also presents symptoms of dyspraxia often seen in children with other diagnoses, such as autism spectrum disorder (ASD). Furthermore, because of its pervasive effect not only on movement but also on self-esteem and well-being, the impact of dyspraxia on development, performance in ADLs, and socioemotional functioning is described. The neuroanatomical mechanisms purported to underlie praxis are reviewed, and SI theory as it pertains to intervention for disorders of praxis is discussed. Finally, related literature that may be germane to sensory integrative-based dyspraxia is examined. To illustrate the characteristics of practic disorders and important concepts of assessment and intervention, the cases of two children, Alyssa and Dalton, are presented.

The Role of Sensation in Movement and Praxis

Knowledge of sensory processing is essential to understanding sensory integrative-based dyspraxia. The performance of efficient and precise voluntary movement requires both the proper planning of movement parameters as well as the integration of sensory feedback (Shumway-Cook & Woollacott, 2011). Information regarding body position in space necessary for praxis comes from integration of numerous senses, including tactile, proprioceptive, visual, vestibular, and auditory senses, as well as interceptive information (Shumway-Cook & Woollacott, 2011). The brain utilizes these inputs from several sensory systems when planning movements and differentially prioritizes the application of these sensory inputs depending on the task being performed (Sober & Sabes, 2005). There is more information on this multisensory process in Chapter 7 (Sensory Discrimination Functions and Disorders).

Ayres (1972b) asserted that motor planning was dependent, in part, on the development of a semiconscious body scheme or internal model of the body in action that began with tactile awareness. "Sensory input from the skin and joints, but especially from the skin, helps develop, in the brain, the model or internal scheme of the body's design as a motor instrument" (Ayres, 1972b, p. 168). Ayres further suggested that somatic changes arising from movement resulted in motor memories that guided ensuing movements. Use of the body for action helped integrate the sensory information and develop the body scheme. Thus, "if the information which the body receives from its somatosensory receptors is not precise, the brain has a poor basis on which to build its scheme of the body" (Ayres, 1972b, p. 170). Although Ayres (1972a, 1972b, 1985) emphasized the contribution of tactile and proprioceptive sensation to the development of body scheme (supported by more recent research by Medina and Coslett, 2010), other investigators have noted important contributions of the vestibular, visual, and auditory systems (Daprati, Sirigu, & Nico, 2010; Lopez, Schreyer, Preuss, & Mast, 2012).

The basics of sensory reception, transduction, and processing within the sensory systems were presented in Chapter 4 (Structure and Function of the Sensory Systems). Praxis relies heavily on discrimination within many sensory systems. The links between praxis and sensory discrimination and integration are presented next, whereas information regarding sensory discrimination function and dysfunction is presented in Chapter 7 (Sensory Discrimination Functions and Disorders).

Tactile System

As discussed in Chapter 4 (Structure and Function of the Sensory Systems), the tactile system detects qualities and location of external stimuli applied to the skin. More broadly, the somatosensory system subserves both perception and action (Dijkerman & de Haan, 2007). It conveys information about the spatial and temporal characteristics of touch, is involved in tactile discrimination of touch and proprioception, and has been linked to behaviors related to praxis (Dijkerman & de Haan, 2007; Lundy-Ekman, 2013; Serino & Haggard, 2010). For example, signals from the tactile system trigger exploratory behavior and serve to guide movement for the purpose of gathering sensation. In addition, the somatosensory system has been shown to be involved in postural flexion through activation of tonic labyrinthine response, programming of complex movement sequences, refined manual dexterity and manipulation, mental representation of objects, and selective attention (Serino & Haggard, 2010). Contributions of the dorsal column medial lemniscal (DCML) system to praxis are summarized in Table 5-1. This pathway transmits information relative to tactile discrimination, deep touch, vibration, pressure, and muscle and joint movement sensations from peripheral receptors to the central nervous system (CNS). Consistent with Ayres' (1972a, 1972b) views on the importance of the somatosensory systems in praxis, in a meta-analysis of motor learning, Hardwick, Rottschy, Miall, and Eickhoff (2013) found that specific loci of activity in the primary somatosensory cortex were present in sensorimotor learning tasks, suggesting an active role for this part of the cortex during motor learning. In addition, the important finding that somatosensory representations are plastic and dynamically changing in response to experience was reported by Medina and Coslett (2010).

TABLE 5-1 Contributions of the Dorsal Column Medial Lemniscal System to Praxis

MOTOR	SELECTIVE ATTENTION, ORIENTATION, AND ANTICIPATION
Initiation of voluntary movements	Unraveling competing stimuli
Performance of complex movement sequences and refined manual dexterity	Initiating and controlling internal search
Handling objects in space	Anticipatory components of sequential behavior patterns
Flexion of joints	

Proprioception

Proprioception refers to sensations of muscle movement (i.e., speed, rate, sequencing, timing, and force) and joint position (Lundy-Ekman, 2013). Proprioception provides the motor system with a map of the external environment and of the body (Blanche, Bodison, Chang, & Reinoso, 2012). Knowledge of the body and movements that come from proprioception are important for the development of a body scheme, for praxis, and for producing adaptive actions (Ayres, 1972b; Blanche et al., 2012; Ito, 2012).

Proprioceptive feedback arises primarily from receptors in muscles, with some contributions made by receptors in skin and joints (Lundy-Ekman, 2013). Golgi tendon organs and muscle spindle receptors, the primary receptors for muscle proprioception, provide the CNS with information about muscle changes during movement, which, in turn, allows generation of the proper amount of force, timing, and sequence of movements needed to act on objects. The somatosensory cortex, in particular, readily adapts to changing input, modifying the body image and enabling skilled performance of tasks (Dijkerman & de Haan, 2007). Proprioception arising from active movement assists in the development of body scheme and actions used to plan complex movements (Kiernan & Rajakumar, 2013). In contrast, passive movement, joint compression, and joint traction do not produce the same level of proprioceptive feedback (Beets et al., 2012). Thus, within an SI approach, active movement is preferred over passive movement.

Vestibular System

The vestibular system is thought to provide an important sensory foundation for praxis, especially the development of bilateral coordination and planning of anticipatory movements (Rine, 2009). The vestibular and proprioceptive systems together contribute to the development of balance, postural control, and integration of postural reflexes (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2012). With its interconnections to the visual and auditory systems and cerebellum, the vestibular system contributes to posture and maintenance of a stable visual field, which allows efficient awareness and movement of the body through space (Kandel et al., 2012; Rine & Wiener-Vacher, 2013). In conjunction with proprioceptive feedback, the vestibular system contributes to the development of neuronal models of how it feels to perform a given movement (Kandel et al., 2012; Kiernan & Rajakumar, 2013), and these models are used later to regulate ongoing activity and guide the execution of future tasks (Brooks, 1986). Deficits in vestibular functioning have been found to result in problems with motor development, balance, and reading abilities (Rine & Wiener-Vacher, 2013).

Vision

Vision is relevant to intervention based on SI theory because of its important contribution to position and movement in space. In combination with the somatic senses (i.e., tactile, vestibular, and proprioceptive) that provide knowledge of the body and its actions, vision yields much information about the surrounding world (Dionne, Legon, & Staines, 2013). Vision provides a contextual framework for the ability to predict and anticipate movement in time and space. In addition, it allows the ability "to visualize one's personal space relative to where things of significance are in one's world and what is possible with the available objects, people, and events" (Kawar, 2005, p. 89). Vision serves three major purposes: learning about objects and objects in space, maintaining posture, and informing us about our position in space (Kandel et al., 2012). The visual system has strong neuroanatomical and functional connections to the vestibular system at the brainstem and cortical levels (Kandel et al., 2012), and the ability to integrate sensory inputs from these two systems is vital to one's ability to move effectively in space. Ultimately, oculo-motor control of eye movements, including saccades, pursuits, and vergent movements, allows one to gather meaningful information from the environment, develop an understanding of objects and their properties, and have spatial awareness.

Ayres (1989) suggested that visual perception and praxis are closely aligned and stated: "A conceptual system common to praxis also appears to serve visual perception" (p. 199). Visual-perceptual problems disturb the sensory information that children with motor coordination problems receive, which, in turn, disturbs their performance of planned movement (Rosblad, 2002). Thus, when all its functions are considered together, vision influences cognition and plays a significant role in adaptation to the environment and, in doing so, influences praxis. Ayres specifically identified visuopraxis as a type of practic deficit related in part to impairments in visual perception and visuomotor function (Ayres, 1989). Similarly, in a retrospective study of 273 children tested on the SIPT, exploratory factor analysis identified a pattern similar to the earlier research of Ayres, which the authors referred to as Visuodyspraxia and Somatodyspraxia (Mailloux et al., 2011). This factor was characterized by high loadings on tests of visual perception and visuopraxis, indicating the close relationship among visual perception, visuomotor, and praxis functioning.

Auditory Processing

Historically, auditory processing has not been considered when addressing praxis. However, research is increasingly supporting the relationship among the auditory system, the vestibular system, and praxis; and increasing numbers of occupational therapists are using sound-based interventions to facilitate motor coordination and praxis skills (Gee, Devine, Werth, & Phan, 2013). The auditory and vestibular systems are functionally and neuro-anatomically interrelated. Both respond to vibration, vestibular to low frequency vibration and auditory to high frequency. Both sets of receptors are housed in the same bony structure, and the fibers carrying primary auditory and vestibular inputs form a single cranial nerve, CN VIII (Kandel et al., 2012). Similarly, it has been shown that there are close interactions between the auditory and motor systems, particularly for timing of movements (J. L. Chen, Penhune, & Zatorre, 2008). This has important implications for praxis.

Processing of auditory inputs may contribute to the organization of movement because it is responsible for providing information regarding the spatial location of objects and events. Research linking the auditory system to praxis is virtually nonexistent, but there are some studies that suggest that the auditory system may be an avenue for enhancing movement. Individuals with neurological problems, such as Parkinson's disease, have consistently been found to improve their gait with exposure to rhythmic auditory inputs (Plotnik et al., 2014). Also, literature on musicians has supported that music and rhythmic tones are important in auditory-motor learning (J. L. Chen, Rae, & Watkins, 2012). Further, studies with children with DCD have found that spatial-temporal motor adaptation in these children is multisensory and that visual and auditory sensory information was used to guide and adapt motor movements (B. R. King, Kagerer, Harring, Contreras-Vidal, & Clark, 2011). Warren, Wise, and Warren (2005) also specified the importance of auditory inputs on motor sequencing, proposing that auditory feedback generated by motor actions was important in motor adaptation and allowed online monitoring of the auditory consequences of behavior.

HERE'S THE POINT

- Dyspraxia is not just a movement disorder; it involves integration of sensory information.
- Numerous sensory modalities contribute to development of an adequate body scheme, which is important for motor planning.
- Research supports neural connections between those that support praxis and those involved in the processing of sensory information: the vestibular, visual, tactile, proprioceptive, and auditory sensory systems.

Assessing Disorders of Sensory Integration and Praxis

Praxis has been assessed using several measures. Using an SI frame of reference, the gold standard assessment for children is the SIPT (Ayres, 1989) as it assesses both motor planning and sensory processing. Other assessments and research protocols that have been used to examine praxis include asking the individual to perform representational and nonrepresentational gestures in response to verbal commands or imitation (following demonstration) (Dziuk et al., 2007; MacNeil & Mostofsky, 2012) and motor skill tests, such as the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2; Bruininks & Bruininks, 2005) or the Movement Assessment Battery for Children—Second Edition (MABC-2; Henderson, Sugden, & Barnett, 2007).

Poor performance on these tests may reflect dyspraxia, although other factors, such as poor visual perception, also may influence performance or reflect a visuodyspraxia. Ideational abilities may be assessed using the Test of Ideational Praxis (Ivey, Lane, & May-Benson, 2014; Lane, Ivey, & May-Benson, 2014; May-Benson &

Cermak, 2007). Sensory histories, the Sensory Profile-2 (Dunn, 2013), the Sensory Processing Measure (Parham, Ecker, Miller Kuhaneck, Henry, & Glennon, 2007), or the Sensory Processing Scale (SENSI; Miller & Schoen, 2012) may be used to gather information from parents and teachers about impairments in sensory modulation and functional difficulties experienced by children. Although historically difficult to assess in a standardized manner, Ayres (1972b) identified clinical observations as being important measures of postural, vestibular, and proprioceptive functions associated with praxis. Based on Ayres' (1972b) original clinical observations, Blanche (2010) published a method for observing a series of clinical observations as well as a test for observing proprioceptive processing with the Comprehensive Observations of Proprioception (COP) (Blanche et al., 2012). Further, Wilson, Pollock, Kaplan, and Law (2000) developed the Clinical Observation of Motor and Postural Skills, and Horowitz has published a test of Motor Observations (http://www.motorobservations.com). More information on assessment using clinical observations can be found in Chapter 9 (Using Clinical Observations within the Evaluation Process). Two case studies are presented next in order to illustrate common characteristics of dyspraxia and to demonstrate the application of assessment methods.

CASE STUDY ■ ALYSSA

Reason for Referral

Alyssa, a girl in first grade, was 6 years and 4 months of age. Alyssa's parents pursued an occupational therapy evaluation from a private occupational therapy clinic to investigate possible problems in SI. They wished to clarify difficulties she was having at home with dressing and getting ready in the morning and in school with pasting, coloring, cutting with scissors, and printing. Alyssa's evaluating occupational therapist interviewed Alyssa's parents, and her mother completed a comprehensive developmental and sensory history. As school observation and teacher interview were not possible, Alyssa's teacher completed a sensory questionnaire. The therapist administered the SIPT (Ayres, 1989; see Chapter 8, Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests, for more information on the SIPT), conducted a variety of formal but nonstandardized clinical observations of neuromotor performance (see Chapter 9, Using Clinical Observations within the Evaluation Process, for more information on clinical observations), and observed Alyssa's performance while playing on various equipment in the clinic.

Parent Interview and Developmental/Sensory History

Alyssa was the product of a full-term pregnancy and normal delivery. She weighed 6 lb, 8 oz at birth and did not experience any neonatal difficulties. She achieved developmental milestones at expected ages: sat at 6 months, crawled at 8 months, and walked at 14 months. Her speech developed normally with single words spoken at 12 months and full sentences at 18 months; mild articulation problems were noted but were not of concern to her parents. As Alyssa got older, her parents became concerned about her lack of independence in dressing, eating, and performing school activities, compared with her older sister's development.

At home, Alyssa's mother expressed concern about her motor development, stating that Alyssa was not yet dressing herself independently, was sloppy in eating, often knocked over her water glass, and was not able to pedal a tricycle until she was 5 years old. When dressing, Alyssa put her t-shirts on backwards and her coat on upside down. She could not manage the zipper on her coat or fasten the buttons on her shirt (see Fig. 5-1). She was not yet walking down stairs reciprocally, and she only recently had learned to pump a swing. Even though she struggled with new motor tasks, she tried hard to do well. She wanted to be able to keep up with her older sister and other children and play the same games that they played.

Although Alyssa played with other children in the neighborhood, many of her friends were younger than she was. Alyssa usually directed the play with her friends toward quiet indoor toys, such as puppets, dolls, and tea parties with her toy dishes. When her friends did not want to play her games, Alyssa was unable to play alone. Her preferred activity was watching television. When her parents bought her toys that required fine motor actions, such as dressing up

FIGURE 5-1 Dressing skills, including donning clothing and manipulating fasteners, may be particularly challenging for children with somatodyspraxia and one of the first problems parents may notice.

dolls or stringing beads to make a necklace, she created fantasy games that re-enacted stories or movies instead of using the toys in more typical ways. Alyssa had a vivid imagination and loved to tell stories. She appeared to be highly creative but often could not demonstrate the actions she described.

Teacher Questionnaire

According to her teacher, Alyssa had difficulty with writing, coloring, and cutting with scissors compared with her classmates. Alyssa's teacher reported that Alyssa could print her name but was not yet able to copy simple words, even when the letters were the same as those in her own name. Alyssa pressed the pencil so hard on the paper that often the point broke. When given a 20-piece puzzle, Alyssa was able to determine the correct location for the pieces but was unable to figure out how to rotate them into place. The teacher reported that Alyssa had excellent verbal skills, which was consistent with information provided by her mother and other observations made by the therapist.

Because Alyssa's daily life concerns potentially reflected a sensory integrative basis, she was administered the SIPT and clinical observations of neuromotor performance. We present the results of this testing in five categories:

1. Tactile discrimination
2. Vestibular and proprioception processing
3. Praxis
4. Form and space, visual-motor, and construction
5. Sensory modulation

Alyssa was cooperative with the evaluator throughout the administration of the SIPT; her SIPT scores are shown in Table 5-2. Even on items that were difficult for her, she attempted to do a good job. She especially did not like the tests that involved building with blocks and finding hidden pictures. When observed in the sensory-motor treatment room, she became frustrated when asked to come up with ideas for play.

Tactile, Vestibular, and Proprioceptive Processing

Alyssa's SIPT scores were significantly low (less than or equal to –1.0 SD) on three of four tactile tests. Relative to proprioception, her ability to remember the direction and extent of passive arm movements (KIN) was in the low average range, but the duration of her Postrotary Nystagmus (PRN) was within the average range. She showed inadequate static and dynamic balance abilities (SWB), her equilibrium responses were slightly delayed, she tended to hold on to the examiner rather than use equilibrium to maintain balance, and clinical observation revealed that Alyssa had low muscle tone and poor proximal joint stability and was unable to assume prone extension or maintain head control while in supine flexion. Alyssa did not demonstrate any avoidance responses to touch, and neither her mother nor her teacher reported any indications of tactile defensiveness. She did not have any evidence of gravitational insecurity or aversive responses to movement. No indication of a drive or craving for increased sensory input was noted.

Praxis

One of Alyssa's lowest scores on the entire SIPT was on Postural Praxis, a test of the ability to reproduce unusual hand, arm, and

TABLE 5-2 Alyssa's SIPT Results

CATEGORY	TEST	STANDARD SCORE
Tactile	Manual Form Perception (MFP)	–1.3
	Localization of Tactile Stimuli (LTS)	0.7
	Finger Identification (FI)	–1.9
	Graphesthesia (GRA)	–1.8
Vestibular and Proprioceptive Processing	Kinesthesia (KIN)	–0.8
	Standing and Walking Balance (SWB)	–2.1
	Postrotary Nystagmus (PRN)	–0.2
Praxis	Postural Praxis (PPr)	–2.3
	Oral Praxis (OPr)	–1.4
	Sequencing Praxis (SPr)	–1.4
	Bilateral Motor Coordination (BMC)	–1.3
	Praxis on Verbal Command (PrVC)	0.1
Form and Space, Visual-Motor, Construction	Design Copying (DC)	–1.9
	Motor Accuracy (MAC)	–1.8
	Constructional Praxis (CPr)	0.6
	Space Visualization (SV)	1.2
	Figure-Ground Perception	0.9

body postures and an important indicator of dyspraxia. Movement sequencing and bilateral coordination were below average. Alyssa's ability to replicate positions and movements of her tongue, lips, and jaw (Oral Praxis [OPr]) was also below average. However, Alyssa was able to carry out movements on verbal command, which often is the case for children with somatodyspraxia who have good understanding of language. On paper-and-pencil tasks, Alyssa showed a right hand preference and used a static tripod grasp. She was able to perform sequential thumb-to-finger touching with her right or left hand only by visually monitoring her fingers; thus, she could not do it with both hands simultaneously. Alyssa's performance was immature, but it was striking that she could perform the action well as long as she could visually monitor her fingers.

Form and Space, Visual-Motor, and Construction

Alyssa's ability to trace a line with a pen (Motor Accuracy [MAC]) and to reproduce two-dimensional forms (Design Copying [DC]) was below age expectations, suggesting difficulty with visual-motor control. The rest of Alyssa's SIPT scores in this category suggested age-appropriate form and space perception and constructional abilities.

Related Testing and Summary

Psychological assessment revealed that Alyssa's IQ score was 132, with a higher verbal than performance IQ. Given her competence with language skills compared with her poorer visual-motor and motor planning skills, we were not surprised that her verbal IQ was higher. A significant difference between verbal and performance IQ score, with lower performance scores, fits a common pattern seen in children with dyspraxia.

From the overall pattern of test scores and observations, the occupational therapist identified somatodyspraxia as a major factor that interfered with Alyssa's performance. Alyssa's dyspraxia appeared to have its basis in poor processing of tactile and vestibular-proprioceptive sensation. Alyssa's dyspraxia involved both gross and fine motor (visual-motor) components. She also appeared to have difficulties with the ideational aspect of praxis.

CASE STUDY ▪ DALTON

Reason for Referral

Dalton was a 7 1/2-year-old boy attending second grade at a local public school. Dalton's teacher reported that he moved about in his seat frequently, often stood up instead of staying seated, and had difficulty paying attention in class. At recess, she reported he was very active, often playing chase and tag games. Sometimes he was unintentionally aggressive with other children, pulling or pushing them to get them to participate in his games. Although he was quite bright and most of his work was at grade level, he had to try very hard to keep up with his classmates. His handwriting was difficult to read and, in frustration, he often scribbled carelessly on his papers. The teacher requested an evaluation from the school occupational therapist. Dalton's parents were surprised at the teacher's request for an evaluation because they believed he was bright and would do well in school. The occupational therapist who evaluated Dalton interviewed his teacher and his parents who also completed a comprehensive developmental and sensory history. The occupational therapist administered the SIPT (Ayres, 1989), observed Dalton during a variety of formal but nonstandardized clinical observations of neuromotor performance, and observed his performance in the classroom.

Parent Interview and Developmental/ Sensory History

Dalton's mother experienced a great deal of nausea during her pregnancy. Dalton was delivered by cesarean section, but no postnatal complications were apparent. His mother described him as a happy but active baby who had poor sleep habits. He crawled only briefly, and walked at 9 months. He began using language before age 1 year. As a preschooler, Dalton had several ear infections but was otherwise healthy. No particular sensitivities to auditory or tactile stimuli were reported, but Dalton was easily distracted. He was having difficulty learning to ride his two-wheeled bicycle and struggled with tasks using both hands, such as buttoning his shirt and tying his shoes. Dalton liked to play soccer, but his mother noted that he frequently tripped on the playing field and could not time his kicking actions appropriately. Often he was observed randomly jumping and running during games. He was initially enthusiastic when trying new tasks, but he quickly lost interest when things did not go well. His mother described Dalton as a "thrill seeker," stating he often engaged in risky behavior, such as climbing to the top of their swing set and trying to crawl across it. He was generally happy and seldom daunted by his poor coordination.

Teacher Interview

According to his teacher, Dalton sat near the front of the classroom and did a great deal of fidgeting and wiggling in his seat. He often looked around at classmates and dropped things on the floor. Dalton generally preferred his right hand for writing but often used his left hand for other tools, such as a fork. He used all five fingers of his right hand to hold the pencil, stabilizing it against his little finger. Dalton used scissors awkwardly with his left hand and struggled to hold the paper in his right. Associated movements were noted in his right hand that mirrored the actions of his left hand. At times, he transferred the scissors to his right hand. He resorted to tearing the paper when he could not maneuver the scissors well.

As in the case of Alyssa, because Dalton's daily life concerns appeared to have a sensory integrative basis, relevant clinical observations and the SIPT were administered. The results of his testing are presented next.

Dalton was eager to try many of the tasks requested by the occupational therapist, and although he was fidgety, he was attentive throughout the one-on-one evaluation. None of his scores reflected severe impairments in performance. In fact, many of his scores on the SIPT were within normal limits. However, the pattern of low scores, coupled with a meaningful cluster of clinical observations, is typical of children with BIS deficits. Dalton's lowest scores are reported in Table 5-3.

Tactile, Vestibular, and Proprioceptive Processing

Dalton did well on most of the tests requiring tactile discrimination. The one exception was Graphesthesia (GRA), which required fine motor skill and two-sided body use in addition to tactile discrimination. He exhibited low proximal muscle tone and hyperextensibility of his

TABLE 5-3 Dalton's Lowest SIPT Scores

TEST	STANDARD SCORE
Kinesthesia (KIN)	−1.2
Graphesthesia (GRA)	−1.0
Postural Praxis (PPr)	−0.9
Bilateral Motor Coordination (BMC)	−1.4
Sequencing Praxis (SPr)	−1.3
Standing and Walking Balance (SWB)	−1.1
Motor Accuracy (MAC)	−1.2
Postrotary Nystagmus (PRN)	−1.2

elbows, wrists, and fingers. He could not assume prone extension or maintain his head position in supine flexion. Dalton displayed poor postural background movements and equilibrium reactions. These factors, coupled with low scores on Kinesthesia (KIN), Standing and Walking Balance (SWB), and PRN, suggested poor vestibular-proprioceptive processing. Dalton also did not exhibit aversive reactions to touch or movement. He was, however, distractible and impulsive when observed in unstructured situations and in group activities, such as playing soccer.

Praxis

Although his SIPT scores were within the average range, Dalton's lowest SIPT scores were on the Bilateral Motor Coordination (BMC) and Sequencing Praxis (SPr) tests, and the Postural Praxis (PPr) test was in the low average range. Clinical observation revealed that tasks requiring bilateral coordination (e.g., jumping jacks, reciprocal stride jumps, and skipping) were poorly coordinated and performed with a great deal of effort. Dalton could not consistently identify his left and right body sides. He carefully monitored isolated movements of his forearms, hands, and fingers with his eyes and moved very slowly when performing simultaneous movements with both hands. In addition, he had a problem controlling his body when jumping through a sequence of squares taped on the floor, throwing and catching balls, and kicking balls that were rolled to him.

Form and Space, Visual-Motor, and Construction

Dalton had difficulty with the MAC test, a pen-and-paper task requiring fine motor control. This score is consistent with his handwriting difficulties.

Summary

From the overall pattern of test scores and observations, the occupational therapist determined that Dalton demonstrated difficulties with BIS. He demonstrated particular difficulties with anticipating body actions and projecting his body through space, both of which impacted his ability to be successful in sports. Dalton's praxis difficulties appeared to have their basis in poor processing of vestibular-proprioceptive sensory inputs, which involved his postural control, bilateral coordination, and fine and gross motor sequencing skills.

Both Alyssa and Dalton showed behaviors consistent with sensory integrative-based practic disorders. The behaviors are notable in their reasons for referral, observations made in the classrooms, parental reports of behavior at home, and standardized testing.

HERE'S THE POINT

- Praxis has been assessed through several measures, with the SIPT (Ayres, 1989) being the gold standard for those using an SI framework.
- Clinical observations of postural and motor skills are an important adjunct to standardized assessment.

Disorders of Praxis

Patterns of Practic Dysfunction

Through time, using different samples of children and various types of factor analyses, Ayres alone (1965, 1966, 1971, 1977, 1989) and with her colleagues (Ayres et al., 1987) identified consistent patterns of practic dysfunction. She identified a link between tactile functions and motor planning as well as a relationship between visual-spatial skills and motor planning. In some analyses, she also identified postural, bilateral integration, as well as motor sequencing problems linked to vestibular processing. Ayres (1989) ultimately identified four major patterns of dysfunction in praxis, which she labeled as:

1. Somatodyspraxia
2. BIS deficits
3. Dyspraxia on verbal command
4. Visuodyspraxia (sometimes combined with somatodyspraxia to be called **visuo-somatodyspraxia**)

Mulligan (1998) subsequently performed factor analyses using more than 10,000 SIPT profiles of children evaluated for possible sensory integrative problems. She identified a factor reflecting generalized sensory integrative dysfunction and four first-order factors that bear similarity to Ayres' dysfunctional groups. Mulligan labeled the first-order factors:

1. BIS deficit
2. Dyspraxia (including all praxis tests *except* BMC and SPr, even those reflecting primarily cortical function, such as Praxis on Verbal Command)
3. Somatosensory deficit
4. Visuoperceptual deficit

More recently, in an exploratory factor analysis using the SIPT and items from the Sensory Processing Measure, Mailloux and colleagues (2011) identified patterns similar to those found by Ayres. They identified patterns of visuodyspraxia, somatodyspraxia, vestibular and proprioceptive bilateral integration and sequencing, tactile and visual discrimination, and tactile defensiveness and attention.

Using a somewhat different approach, May-Benson (2005) examined patterns of practic dysfunction related to the ideational aspect of praxis, an area that had not been addressed in any of the previous pattern analyses of praxis. She conducted a cluster analysis on three groups of age- and gender-matched children (children with motor planning problems alone, with motor planning and ideational problems, and typical peers). Tests included those of motor coordination, ideation, motor planning, language, behavior, and executive function. She identified five cluster groups, two of which reflected average and above average skills. Practic deficits were identified in the other cluster groups by general order of severity:

- Generalized dysfunction—low scores on all tests.
- Dyspraxic group—average ideation scores but below average motor coordination and motor planning skills, attention and behavioral regulation, and average language skills.
- Ideational dyspraxic group—well below average ideational skills (below those of generalized dysfunction), below average motor coordination and manual motor skills, but average finger tapping and imitation of hand skills, below average attention and behavioral regulation, average executive planning, and above average language skills.

Thus, ideational difficulties, although clearly related to motor planning problems, likely represent an additional aspect of dyspraxia.

Ayres (1989) sought to differentiate among patterns and subtypes of practic dysfunction as a step toward developing intervention strategies tailored to the individual child. Additional research using the SIPT by Ayres, Mailloux, and Wendler (1987) and Lai, Fisher, Magalhães, and Bundy (1996) strongly suggests that praxis likely is a unidimensional construct that may practically distinguish between *different aspects* of practic deficit. Using the Rasch analysis, Lai and colleagues (1996) found that SIPT praxis tests associated with BIS were more difficult than those associated with somatodyspraxia, suggesting that BIS may represent a less severe form of practic disorder and that somatodyspraxia and BIS may be viewed as two aspects of the same dysfunction. May-Benson (2005) suggested that ideational problems may exist with or without concomitant motor planning problems. Clearly sensory-based dyspraxia is manifested in several ways in different children. Thus, the clearest interpretation of an individual child's profile might be to say that there is evidence reflecting generalized sensory integrative dysfunction with particular deficits in sensory processing, ideation, or aspects of motor planning.

Ideational Dyspraxia

Ayres (1985) stated,

> Ideation or conceptualization is central to the theory of dyspraxia. . . . [It] is a cognitive or thinking process. Before one can engage purposefully or adaptively with a physical object, large or small, one must first have the concept of possible person-object interaction. . . .

> Ideational praxis is an essential skill underlying all use of objects to obtain a goal that may or may not be independent of the objects. (p. 20)

She further stated that ideation involves conceptualizing the goal for an action and some idea of how to achieve that goal. Ideation, therefore, involves both generating a goal and identifying the general steps needed to accomplish that goal (Ayres, 1985). Further, ideation is largely a cognitive process that ultimately contributes to a child's ability to be creative and playful as he or she interacts with the environment. Ideation is an important foundational ability for pretend play as seen in children with ASD (Rutherford & Rogers, 2003).

Problems in ideation have historically been thought to occur in children with severe dyspraxia and most often in those with cognitive or intellectual delays (Ayres, 1985), and little has historically been known about these children. More recently, May-Benson (2005) found that ideational problems existed independent of motor planning problems and were identifiable in nearly half of her population of children with dyspraxia, indicating that ideational difficulties are more prevalent than previously believed. Children with ideational problems were found to have fewer or less complex ideas for actions. In addition, in examining the characteristics of children with ideational problems, May-Benson (2005) further found that a subgroup had above-average intelligence and language skills, thus indicating that although ideational difficulties may occur in individuals with cognitive deficits, it is not a necessary condition for ideational dyspraxia.

Characterizing ideational deficits in children relies heavily on what has been observed clinically. Literature relative to ideational deficits in adults is presented in the text that follows, and many of the characteristics described here are extrapolated from this knowledge base (May-Benson, 2000). Children with ideational deficits are often observed to have difficulty knowing what to do, even with familiar toys and objects. They may stand and watch others, avoid participation in free play activities, or be followers instead of leaders. They have a limited repertoire of actions with which to interact with the world, and they tend to repeat those actions instead of trying new ways to approach a task. They do not recognize which actions are afforded by which object properties and, therefore, often use objects in inappropriate ways. Play skills are observed to be particularly difficult for children with ideational problems. They have difficulty representing objects; thus, creative or imaginative play is adversely impacted. Some children with ideational problems may do well with structured play, such as sports, but have difficulties with free-play situations. Some children with ideational problems, such as Alyssa, use their imagination to tell stories but struggle with conceptualizing ways to act on objects. In Alyssa's case, her high intelligence may have supported her story making and language abilities, but she could not engage in dynamic physical interactions using her body. She was intelligent enough to know that she did not perform as well as her peers and compensated by seeking younger companions and sedentary play.

Somatodyspraxia

Somatodyspraxia is characterized by poor planning of both movements that are anticipatory and feedforward-dependent as well as actions that depend on sensory feedback. Therefore, children with somatodyspraxia exhibit difficulties with planning the same kinds of tasks that are problematic for individuals with deficits in BIS as well as some generally easier tasks (Ayres, 1989). Children with somatodyspraxia generally show a characteristic pattern of test scores on the SIPT and clinical observations (Ayres, 1989). Low scores commonly noted on the SIPT are PPr, BMC, SPr, and OPr. Alyssa had low scores on all these measures. Constructional Praxis (CPr) and Praxis on Verbal Command (PrVC) scores may also be low, as may DC and MAC, reflecting problems in visual spatial skills. Motor skills that are often difficult for individuals with somatodyspraxia include the ability to assume supine flexion, sequential finger touching, the ability to perform rapid alternating movements (diadokokinesis) (see Chapter 9, Using Clinical Observations within the Evaluation Process), and in-hand manipulation skills (Exner, 1992). Alyssa demonstrated most of these difficulties. Further, interviews with parents and teachers often report difficulties related to daily routine. Delays in the acquisition of self-care skills, poor organization, difficulty manipulating and assembling toys, and strained relationships with siblings or playmates (or a history of these) are commonly reported.

For somatodyspraxia to have a sensory integrative basis, it must be accompanied by evidence of poor somatosensory and sometimes vestibular or proprioceptive processing. Alyssa and many others with somatodyspraxia have low scores on tactile tests of the SIPT, including Manual Form Perception, Finger Identification, and Localization of Tactile Stimuli. Because deficits in BIS based in poor vestibular and proprioceptive processing seem to represent a higher level of practic dysfunction than somatodyspraxia (Lai et al., 1996), it is reasonable to suspect that many clients with somatodyspraxia will also have difficulty with measures of vestibular and proprioceptive processing. In addition, some children with somatodyspraxia demonstrate visual-spatial problems resulting in a visuo-somatodyspraxia.

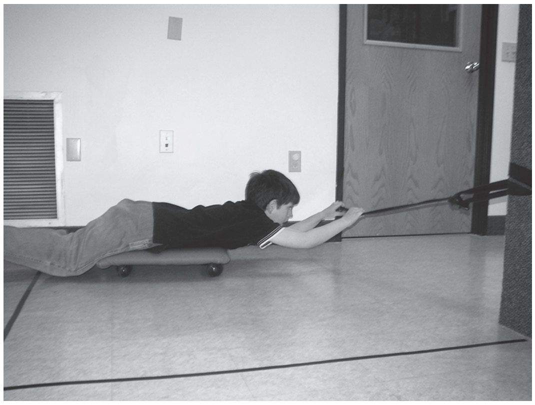

FIGURE 5-2 Children with BIS may have difficulty coordinating their upper extremities to push and pull themselves while on a scooter.

Bilateral Integration and Sequencing (BIS) Deficits

BIS problems appear to be a relatively mild form of practic disorder; thus, BIS deficits are generally subtle. They involve poorly coordinated use of the two body sides, deficits in performing sequences of movement, and usually poor postural-ocular skills. BIS deficits that are sensory integrative in nature are hypothesized to reflect impaired processing of vestibular and proprioceptive sensations and to have their foundation in poor postural-ocular skills (Ayres, 1985; Mailloux et al., 2011). Although literature supporting a direct neurophysiological link between vestibular dysfunction and bilateral coordination skills is minimal, there is support for a relationship between vestibular functioning and postural mechanisms (Lin et al., 2012; Majernik, Molcan, & Majernikova, 2010; Peterka, Statler, Wrisley, & Horak, 2011). Further, vestibular inputs are important for the use and integration of many postural reflexes, such as the tonic labyrinthine reflex and asymmetrical tonic neck reflex, among others (Kandel et al., 2012).

Bilateral coordination difficulties are routinely found in conjunction with difficulties with projected action sequences or anticipatory actions involving timing and movement through space. Projected action sequences, which include actions such as running across a field to catch a ball, have their basis in vestibular and proprioceptive inputs and rely heavily on the integration of visual and movement sensory inputs (Schaaf et al., 2010). Therefore, during clinical observations, a child who has BIS deficits may demonstrate right–left confusion; poor lateralization of hand function; avoidance of midline crossing; and poor ability to do motor skills such as skipping, jumping jacks or stride jumps, riding a bicycle, catching or throwing a ball, cutting with scissors, or stabilizing one's paper when writing. Oculo-motor difficulties, such as problems with visual tracking, convergence, and saccades, are routinely found with this problem. On the SIPT (Ayres, 1989), scores on BMC and SPr are generally low in conjunction with low scores on PRN and SWB. Ayres also found low scores on GRA and OPr to be associated with deficits in BIS as they involve motor sequencing. These measures are described more fully in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests). Dalton's SIPT scores reflect this pattern. His lowest scores were on BMC and SPr, and he had difficulty with all clinical observations that reflect BIS. Other motor assessments may reflect difficulties in balance skills, ball skills, and gross and fine motor coordination tasks (see Fig. 5-2).

HERE'S THE POINT

- Patterns of practic dysfunction remain relatively consistent across studies and include somatodyspraxia, BIS problems, ideational dyspraxia, and related visuopraxis and visuo-spatial deficits.

- Children with ideational problems have difficulties generating goals for ideas and some idea of how to achieve the goal.
- Children with somatodyspraxia typically have problems with processing tactile and proprioceptive sensory inputs and have difficulties with motor planning, which may be seen in conjunction with visual-spatial or visuopraxis problems.
- Children with BIS difficulties have problems processing vestibular-proprioceptive inputs and have difficulties coordinating two parts of the body, sequencing actions, and anticipating actions.

Neuroanatomical Bases of Praxis

The neuroanatomical aspects of the sensory systems are described in Chapter 4 (Structure and Function of the Sensory Systems). This section examines the neuroanatomical underpinnings specific to praxis and discusses areas of the brain thought to be involved in conceptualizing, planning, sequencing, and initiating action, all important components of praxis. Although many regions of the brain contribute to praxis, there are no neuroanatomical loci clearly and uniquely implicated in developmental dyspraxia. Difficulty localizing a specific neurological "substrate" or "locus" for developmental clumsiness supports the viewpoint posited by Luria (1963, 1980), Tracy and colleagues (2003), and Hardwick and colleagues (2013) that praxis is dependent upon a complex functional system or network involving cortical and subcortical structures with different brain structures participating in different phases of motor learning.

Despite the absence of a clearly defined praxis loci or pathway, there are, nonetheless, functional and structural differences identified by lesion studies, motor learning studies, and by functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) in typical adults and in adults with apraxia. However, although we can draw upon this information, it is likely that the mechanisms underlying developmental dyspraxia are not the same as those in the adult with known acquired brain injury.

In the next section, brain structures believed to be associated with ideation, planning, and execution of action are examined.

Ideation

Ideation has been identified as a cortical function that involves conceptualization of "knowing what to do" in motor actions (Jeannerod & Decety, 1995), but the process of ideation is still not well understood. In adult apraxia, ideational apraxia is described variably as a problem in both pantomiming and imitating object use or as a problem with sequential use of objects; in both cases, the primary deficit is believed to be a problem with having the "idea" or conceptualization of the motor action (Roy et al., 2014). In children, ideational deficits are viewed more broadly as a deficit in generating a goal for an action and some idea of how to achieve the goal (Ayres, 1985). May-Benson (2001) proposed that the ability to generate ideas for action was the result of interactions of the person with objects or the environment. Ideas for action were thought to originate, in part, from external sensory stimuli and internal models or memories of past experiences. The abilities to represent motor actions and generate motor images were identified as vital components of the ideation process (Brooks, 1986; Gentsch, Weber, Synofzik, Vosgerau, & Schütz-Bosbach, 2016). Cognitive functions of knowledge of objects, knowledge of actions, knowledge of serial actions, and knowledge of appropriate object-action interactions were identified as being necessary for the effective development of ideas for actions (Roy et al., 2014).

As with praxis in general, ideation cannot be localized to one area of the brain. Studies with adults with strokes who have apraxia and associated ideational deficits demonstrate damage to the left hemisphere (Harrington et al., 2000). Malkani and Zadikoff (2011) proposed that ideational apraxia in adults was related to damage to the left parietal-occipital (region around where the parietal and occipital lobes meet) and parieto-temporal regions (region around where the parietal and temporal lobes meet) of the brain as well as possible areas in the left frontal regions (see Fig. 5-3). Importantly, these regions correspond to visual-somatosensory and visual-auditory integration areas. Thus, primary sensory areas, in particular the left parietal areas, receive sensory inputs, and association areas integrate information and establish necessary spatial-temporal information for action. The prefrontal cortex plays a major role in setting goals and is active when we perform (or even imagine performing)

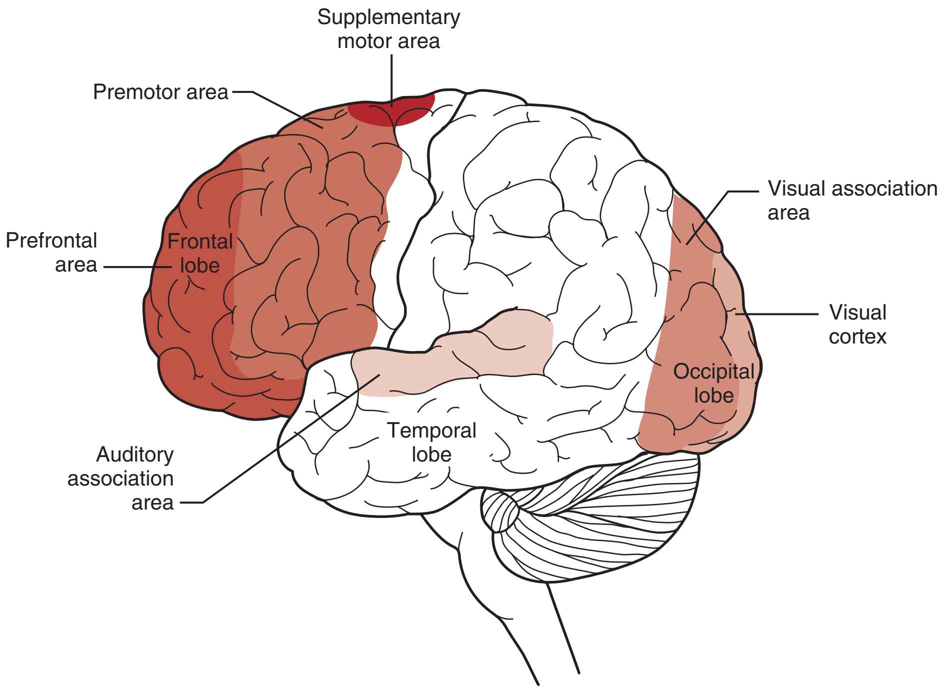

FIGURE 5-3 Regions of the cortex showing the parietal, occipital, temporal, and frontal lobes, as well as the primary motor, primary sensory, and prefrontal regions.

complex, goal-directed sequences of movements, particularly in novel situations (Fuster, 2008). The supplemental motor area (SMA) organizes actions and is proposed to be involved in goal recognition and motor imaging of actions. Indirect connections for ideation with the limbic system, basal ganglia, and cerebellum may also play some role in accessing information for idea generation, imaging, organization of action, and initiation (May-Benson, 2001). Future research using brain imaging technology is needed to specifically examine which structures are involved in ideation.

Planning, Motor Learning, and Execution

Various aspects of the brain are involved in motor planning and motor learning. In a quantitative meta-analysis and review of the functional imaging literature of motor learning in typically functioning right-handed adults, a bilateral cortical-subcortical network was consistently found to underlie motor learning (Hardwick et al., 2013). Brain regions in this network included the dorsal premotor cortex (dPMC), SMA, primary motor cortex, primary somatosensory cortex, superior parietal lobe, thalamus, putamen, and cerebellum (Hardwick et al., 2013). Further, activity in the basal ganglia and cerebellum was stronger for sensorimotor tasks that emphasized the learning of novel movement kinematics and dynamics. Consistent activation of the left dPMC across multiple activities suggested it plays a critical role in motor learning.

Both the lateral premotor cortex (lPMC) and medial SMA play important roles in the translation of a movement strategy into movement tactics (the "how to do it") (Purves et al., 2012), selection of appropriate movements (Shumway-Cook & Woollacott, 2011), and other features of motor planning (Hardwick et al., 2013). The lPMC is active when movement occurs in response to external events (e.g., a driver stops when a traffic light changes from green to red) (Shumway-Cook & Woollacott, 2011). The SMA depends primarily on proprioceptive inputs and is activated when action is self-initiated (Shumway-Cook & Woollacott, 2011). The PMC has also been shown to play a role in the preparation and anticipation of movement (Lohse, Wadden, Boyd, & Hodges, 2014; Purves et al., 2012). See

HERE'S THE EVIDENCE

In a recent review (meta-analysis) of skill acquisition in healthy adults using neuroimaging as a function of length of practice, Lohse and colleagues (2014) reported that across time scales, there were consistent decreases in activity in the prefrontal and premotor cortex, the inferior parietal lobes, and the cerebellar cortex, indicating that these areas may be most important in the earlier learning phase. Similarly, across time, increases were noted in the supplementary and primary motor cortex and dentate nucleus. At the longest time scale, increases were seen in the posterior cingulate gyrus, primary motor cortex, and striatum (putamen and globus pallidus). Further, activity in the striatum was more rostral in the medium time scale and more caudal in the longer time scale. These data support the fact that both a cortico-cerebellar system and a cortico-striatal system are active but at different time points during motor learning.

the box, Here's the Evidence, for more information regarding the work by Lohse and colleagues.

Areas 5 and 7 of the parietal cortex (see Fig. 4-7 for details of these numbered Brodmann's areas) are other major sites of convergence of bilateral somatosensory inputs from the body with input from other sensory systems (Dijkerman & De Haan, 2007). Indirect vestibular signals may also project to area 5. There is evidence that cells in area 5 begin firing before movement is initiated and then continue to fire even under conditions of deafferentation and immobilization of joints (Dijkerman & De Haan, 2007). This suggests that some of these cells may play a role in planning active movement (Kandel et al. 2012). Area 5 has close connections with precentral motor areas, including the SMA, further suggesting a role of proprioceptive inputs to motor planning (Kandel et al., 2012). Activity is also shown in area 7A of the parietal cortex (superior parietal lobule or SPL) during motor learning. Hardwick and colleagues (2013) suggested that the superior parietal lobe integrates visual and somatosensory inputs and routes these multimodal outputs to the dPMC, a key hub for motor learning.

The basal ganglia receives significant input from the SMA and, via the thalamus, projects back to this region. The basal ganglia participates in the initiation of movement, but its role may be dependent on context—that is, it may play its role when movements are complex enough to require sequencing (Lundy-Ekman, 2013). Although basal ganglia neurons are active at the onset of movement, their activity increases after movement initiation. Thus, the basal ganglia are most important in the completion of movement. The functions of the basal ganglia are not limited to motor behavior and include emotional, motivational, and associative, as well as cognitive functions (Lundy-Eckman, 2013; Nelson & Kreitzer, 2014). The ventral system of the basal ganglia receives information primarily from the limbic system. These connections may subserve motivation and emotion important to praxis.

The cerebellum receives primary sensory inputs from the vestibular system and has a major role in both the planning and execution of coordinated movement. It serves to compare actual and expected sensory outcomes of movements and determines if changes to the motor command must occur to achieve the desired response. The cerebellum regulates the timing and force of movements to allow smooth, accurate, and rapid movements through feedforward control of muscle contractions (Kandel et al., 2012), and plays an active role in motor planning.

Ito (2012) suggested that cerebral cortical models of movements and actions are developed during the initial learning of motor actions. He posited that internal cerebellar models or action schemas are developed based on body schemas (continually undated maps of one's body shape and posture) and motor schemas (one's long-term memories of movement that are retrieved and control further complex actions and motor skills). Research by Schmahmann, Anderson, Newton, and Ellis (2002) found that the cerebellum also plays a vital role in cognition skills, such as constructing "intentional representations of the world and our bodily activities in the world." These authors stated that the cerebellum is essential for an individual's ability to fully realize self-conscious sensorimotor experiences. This viewpoint is consistent with SI theory that one must "internalize" body actions to effectively and adaptively move in the environment. In addition, the ability to represent one's world and actions is believed to be vital for the development of ideational abilities. Other researchers have found that the cerebellum also plays a role in neurocognitive development, executive functions, working memory, attention, and emotional regulation, all of which can influence our motor performance and ability to develop practic skills (Koziol et al., 2014).

The motor cortex provides a mechanism for the execution of the movements that are selected when performing a voluntary action. Neurons in the primary motor cortex receive and encode ongoing input about the speed, direction, and velocity of movement (Kandel et al., 2012). This feedback comes from somatosensory input to the thalamus as well as intracortical projections from the primary sensory cortex. Information from the primary motor cortex (M1), the PMC, and the primary sensory cortex is transmitted to the muscles for execution via the corticospinal and corticobulbar pathways. Corticospinal fibers synapse in the spinal cord with lateral (lateral corticospinal fibers) and medial (ventral corticospinal fibers) motor neurons, carrying signals to muscles that will execute the motor command. The motor system relies on a continuous flow of sensory information describing the environment, the position and orientation of the body and extremities, and mechanical information about muscle contraction both before and during task performance. In addition, for volitional movement to occur, integration between and among brain structures responsible for all levels of motor output is required.

Neuroimaging Findings in Children with Dyspraxia or DCD

Although there has not been fMRI research conducted with children with dyspraxia (defined using the SIPT), several recent studies have examined neural correlates in children with DCD (reviewed in Zwicker, Missiuna, Harris, & Boyd, 2012). These studies indicated that there were neural differences in activation in various brain structures as well as different patterns of networks, with some areas or connections increased and others decreased. Differences between children with DCD compared with those in a control group were present in both motor and nonmotor tasks. Researchers looking at children with DCD suggested possible somatosensory, proprioceptive, or internal models or body scheme impairments in this population. This view is remarkably similar to the hypotheses put forth by Ayres (1972b) in her early work.

HERE'S THE POINT

- Praxis is dependent on a complex functional neural system including the motor cortex, somatosensory cortex, prefrontal cortex, premotor area, parietal lobe, basal ganglia, and cerebellum.

Related Diagnoses and Terminology

The term *dyspraxia* is used often, but not exclusively, to describe a sensory integrative-based praxis disorder—that is, not all children who have dyspraxia have sensory integrative dysfunction. In fact, Ayres (1985) described some children as having dyspraxia even though their difficulties were not based on poor sensory processing. To further complicate matters, a child diagnosed with sensory integrative-based dyspraxia by an occupational therapist may be diagnosed differently by another professional as not all disciplines evaluate sensory processing.

Related Diagnoses

Common related diagnoses include DCD (American Psychiatric Association, 2013) and DAMP (deficits in attention, motor control, and perception) (Gillberg, 2003). Although we cannot assume that sensory integrative-based dyspraxia, DCD, or any other related diagnoses refer to the same condition, the terms are all used in studies examining children's motor skills, and there are similarities in characteristics across diagnoses. Gubbay (1975) first described the problems of "clumsy children," also referred to as children with "developmental apraxia." He believed that clumsy children had difficulty performing skilled, purposeful movements not related to *primary* sensory, motor, or cognitive deficits. Instead, Gubbay (1985) noted that 50% had pre-, peri-, or neonatal complications, a finding confirmed by May-Benson, Koomar, and Teasdale (2009). Recent research has shown that preterm birth and low birthweight are also strong risk factors for DCD (Zhu, Olsen, & Olesen, 2012; Zwicker, Yoon, et al., 2013). Similar to Gubbay's early description of clumsy children, Zwicker, Harris, and Klassen (2013) reported a DCD prevalence of 5% to 6% in school-aged children, although this varied depending on the diagnostic criteria and familiarity of professionals with the condition. Also similar to Gubbay is the finding that DCD is two to seven times more common in boys than girls (American Psychiatric Association, 2013). Piek and Coleman-Carman (1995) found that children with DCD performed significantly poorer on a test of kinesthetic perception and movement than matched control subjects, which is similar to the tactile-kinesthetic impairments that Ayres (1972a, 1985) described in children with dyspraxia. In other diagnostic systems, the *International Classification of Diseases and Related Health Problems* (*ICD-10;* World Health Organization [WHO], 2010) includes a diagnosis of "specific developmental disorder of motor function" in which clumsiness is the key feature. The main feature is a serious impairment in motor coordination development that is not explained by intellectual delays. The draft version of *ICD-11* uses the broader term of *developmental motor coordination disorder,* which is marked by "severely impaired coordination . . . in the context of otherwise normal development of cognitive and social skills."

Many studies have reported an overlap between attention deficit-hyperactivity disorder (ADHD) and DCD (Kirby, Sugden, & Purcell, 2014). Children who are impulsive and distractible may often fall or bump into objects and appear clumsy because they are not paying attention to what they are doing, but may not have motor planning problems. In Scandinavia, DAMP is indicated when there are concomitant deficits of attention or hyperactivity and DCD (Gillberg, 2003). Landgren and colleagues (1996), studying a group of 589 children who were 6 years old, found that up to 75% of children with DAMP could also be diagnosed with ADHD. Those with DAMP had more deficits in perception and motor function, whereas impulsivity was most indicative of children with ADHD alone. Brossard-Racine, Shevell, Snider, Belanger, and Majnemer (2012) examined a cohort of 49 children newly diagnosed with ADHD, in which 73.5% of the children were identified with motor impairment at baseline that persisted, even after medication, in 55% of the sample. In a retrospective study of 309 children with ADHD, Mulligan (1996) found that the Postural Praxis test of the SIPT was one of the lowest scores (mean z-score –1.36) of this group, although the SIPT praxis tests as a whole did not differentiate children with ADHD from children with other diagnoses.

Praxis and Autism Spectrum Disorders

Another diagnosis that has received considerable attention in recent years in motor performance literature is that of ASD. Individuals with ASD have a range of motor impairments including difficulty with balance, posture, gait, gross motor skills, fine motor skills, and motor planning and praxis (Miller-Kuhaneck & Watling, 2010). Although motor symptoms are not considered a core symptom of ASD in the *DSM-5* (American Psychiatric Association, 2013), these symptoms are highly prevalent in individuals with ASD (Hilton, Zhang, White, Klohr, & Constantino, 2012; Miller-Kuhaneck & Watling, 2010) and are present from infancy (Esposito & Venuti, 2008; Landa & Garrett-Mayer, 2006; Ozonoff et al., 2008). Fournier and colleagues (2010) conducted a meta-analysis on studies examining motor difficulties in individuals with ASD and found large effect sizes for a wide range of motor behaviors across all ages. The investigators suggested that motor coordination deficits should be considered a cardinal feature of ASD. Mostofsky and colleagues (2006) found that children with ASD performed more poorly than those in a control group on multiple aspects of praxis. Similarly, Dziuk and colleagues (2007) found that children with ASD showed impairments in motor planning as measured by imitation, gesture production, and tool use, and that these practic impairments could not be accounted for by basic motor impairment. Because of the close relationship between impairments in praxis and social-communication and behavioral features of autism, Dziuk and colleagues also suggested that dyspraxia should be considered a core feature of ASD. Supporting this, MacNeil and Mostofsky (2012) have suggested that praxis impairments, versus general motor impairments, are unique to autism.

Since Ayres' (1965, 1972b) initial formulations on the role of somatosensation in the development of adequate body schema necessary for motor planning, the SIPT has been used to assess praxis in children with ASD in several studies. Roley, Mailloux, Parham, Schaaf, Lane, and Cermak (2015) found that children with ASD had low scores on tests of postural, oral, and sequencing praxis, as well as low scores on the somatosensory test involving tactile discrimination and kinesthetic awareness. The mean scores for children with ASD were more than a standard deviation below that of the control group, suggesting deficits in both tactile processing and praxis. Similarly, Williams and colleagues (2006) found that four of six measures of tactile and kinesthetic perception differentiated children with high functioning autism from their typically developing peers, indicating tactile perceptual impairments. In contrast, using a different measure of tactile perception, O'Riordan and Passetti (2006) did not find a significant difference in tactile discrimination (texture discrimination; Von Frey hairs) between individuals with and without autism. Abu-Dahab and colleagues (2013) reported mixed findings; children and young adults with high functioning autism did not perform differently from those in a control group on simple tactile tests (simple touch, sharp dull discrimination, or fingertip writing), but they did show significantly lower scores on tests of stereognosis and finger recognition. Given the findings of these studies, it is likely that some, but not all, children with ASD and poor praxis also have poor somatosensation or that some children with ASD demonstrate adequate tactile perception for simple tasks but show impairments on the more complex tactile perception tasks.

In addition to differences in somatosensory processing and praxis functions, various neural and genetic differences related to motor performance have been noted in children with ASD. Functional imaging studies in individuals with ASD have identified abnormalities within brain structures (and connections between brain areas) related to motor performance including larger total brain, cerebellar, and caudate nucleus volumes with reduced corpus callosum (Stanfield et al., 2008). Functional MRI studies also have shown different patterns of neural activity in individuals with ASD in areas of the brain related to motor control and motor learning (Verhoeven, de Cock, Lagae, & Sunaert, 2010; Zwicker, Missiuna, Harris, & Boyd, 2010). Thus, there appears to be a neurobiological basis for the motor impairments that are noted in children with ASD. Lastly, Hilton and colleagues (2012) found a high degree of correlation between motor impairment scores and severity of autism in concordant identical twins in comparison with nonidentical concordant siblings, suggesting a genetic contribution to motor impairment.

HERE'S THE POINT

- Diagnostic terms related to praxis and dyspraxia may vary by discipline.
- DCD and DAMP have overlapping symptoms.
- Research on motor and praxis skills in related diagnoses may inform understanding of dyspraxia.

Dyspraxia Across Ages

Little research is available on the specific impact of dyspraxia on the daily living skills of children. Numerous studies, however, document the developmental, motor, play, and daily life difficulties of children with DCD. As there is much overlap between DCD and dyspraxia, much information in the following section will be drawn from studies on children with DCD.

Early Childhood

Young children with dyspraxia often demonstrate a history of early developmental challenges. May-Benson and colleagues (2009) examined the early developmental characteristics of 1,000 children with sensory processing disorders. Although not examining dyspraxia specifically, they found that 43% of children with sensory processing problems had atypical crawling development, meaning they either crawled very early or late or for a brief period, all potential indicators of inadequate praxis. Parents also frequently reported that children with sensory processing problems had difficulties with colic, jaundice, strong preferences for certain positions, and hesitancy when learning to navigate stairs. Additionally, parents of children with sensory processing problems reported that 33% of these children were not saying words by age 12 months, 31% experienced eating problems, 32% had sleeping problems, and 45% were reported to not go through the "terrible twos."

Functionally, difficulties in praxis for very young children are most often found in delays or difficulties in development of ADLs such as self-care (e.g., fastening buttons, blowing the nose). They may also struggle with manipulating toys and engaging in independent play activities (e.g., puzzles, cutting and pasting, coloring, and playground equipment). Asonitou and colleagues (2012) found significant relationships among cognitive, motor, and manual dexterity skills in 5- and 6-year-old preschool children with and without DCD. Consistent with literature on older children with clumsiness, these preschoolers with DCD performed more poorly than typical peers on all motor and cognitive tasks with significant differences in gross and fine motor skills and developmental play skills. Engel-Yeger (2015) further found that frequency of engagement and social interaction in play was significantly different as children with coordination difficulties spent more time as onlookers, or in transition, than typically developing peers. Children with DCD are also reported to be involved more frequently in an aggressive incident and show a higher frequency of negative affect than the control children during play (Kennedy-Behr, Rodger, & Mickan, 2011).

Dyspraxia or DCD also may be related to a variety of social-emotional difficulties. In a recent questionnaire, parents of preschool children with DCD reported their children were less independent than peers and showed less enjoyment while participating in play, leisure activities, social interaction, and educational tasks (Bart, Jarus, Erez, & Rosenberg, 2011). Further, motor ability was found to be related to anxiety, depression, and emotional recognition in young preschool children with DCD (Piek, Bradbury, Elsley, & Tate, 2008).

School Years

Elementary school often marks a turning point for children with dyspraxia. Problems become even more obvious as the requirements of daily events at home and school increase. Skill areas of self-care (particularly dressing), bathing and personal hygiene, toileting, and eating become areas of difficulty (Engel-Yeger, 2015). Morning routines may turn into battles as the time required for dressing and other self-care activities lengthens, requiring children to receive help, be late for school, or arise very early. Furthermore, problems with completing daily routines were found consistently across families and cultures (Summers, Larkin, & Dewey, 2008). Also, as children get older, they may be required to participate in activities they previously avoided. Parents in this study reported that although older children were expected to participate more independently in the daily routine, parents provided more structure and assistance to children with DCD, and the parents' expectations of independent performance were lower. Children with DCD required consistent prompting and more structure to complete morning tasks within the allotted time. Children with DCD were reported to be happier on weekends and holidays when demands were more relaxed. Parents may become frustrated by the child's inconsistency in performance and may attribute problems to carelessness or laziness (Morris, 1997).

Difficulties playing ball games, getting dressed, and participating in organized sports are issues that are frequently cited for children with DCD at this age (Magalhães, Cardoso, & Missiuna, 2011). Play skills such as bike riding, skipping rope, and ball activities often are performed with difficulty. Finally, organized sports and physical education become increasingly important, and children with dyspraxia often experience difficulty in these areas. Boys with DCD were found to be lonelier and have less participation in group physical activities (Poulsen, Ziviani, Cuskelly, & Smith, 2007). In a cross-cultural study, Cermak, Katz, Weintraub, Steinhart, Raz-Silbiger, Munoz, and Lifshitz (2015) reported that these lower levels of participation and decreased physical activity were associated with decreased fitness and an increased risk of obesity in children with DCD. Overall, studies of quality of life in children report significantly poorer results in physical, psychological, and social functioning in children with DCD compared with peers (Zwicker, Harris, & Klassen, 2013). Further, Mandich, Polatajko, and Rodger (2003) reported that children with DCD were often bullied, teased, and left out of peer groups because of their motor difficulties. These experiences resulted in feelings of incompetency, which negatively impacted their self-esteem.

By the third and fourth grades, a dramatic increase in the demand for written output occurs, and many children experience difficulty with handwriting and art projects that involve cutting, coloring, pasting, and assembling. Levine (1987) first used the term *developmental output failure* to describe the problem of children who could not produce sufficient academic work to meet expectations. Output failure may be caused by poor visual-motor coordination, form and space perception, motor planning or motor memory, fine motor skill, organization or sequencing, or somatosensory processing. Failure to keep up with the amount of work required may result in a decline in grades, motivation, and self-esteem (Levine, 2003). McHale and Cermak (1992) determined from observations in second, fourth, and sixth grade classrooms that 30% to 60% of the school day was devoted to fine motor tasks. Writing was the predominant fine motor task, used for copying text, taking notes, drawing, writing from dictation, creative writing, and completing worksheets and workbooks. Magalhães and colleagues (2011) had identified handwriting as problematic in children with DCD. Handwriting problems may be characterized by illegibility that results from disorganized or nonuniform letters, improper spacing, inappropriate slant, or poor stroke quality (Goldstand, Gevir, Cermak, & Bissell, 2013). Problems in these areas are major reasons why school-aged children are referred for occupational therapy (Goldstand et al., 2013). As pressure mounts for handwriting to be introduced to children at younger ages, it is likely that these difficulties will become increasingly prevalent in our schools.

Adolescence and Adulthood

Historically, parents were told that children with coordination difficulties would outgrow them; however, several follow-up studies found motor skill deficits identified at age 5 years persisted into adolescence (Cantell, Smyth, & Ahonen, 1994; Cousins & Smyth, 2003; Losse et al., 1991), with poorer motor skills, lower academic achievement, lower IQ scores, and more behavior problems reported in these children compared with typical peers. Another follow-up study of 16-year-olds with DAMP found more speech and language disorders, longer reaction times, greater clumsiness, and higher rates of accidents resulting in bone fractures than adolescents who had no history of DAMP (Hellgren, Gillberg, Gillberg, & Enerkskog, 1993). Additionally, executive functioning, including working memory and the ability to plan goal-directed tasks, is a key area of dysfunction for young adults with motor coordination difficulties (Kirby, Edwards, & Sugden, 2011). Behaviorally, problems with praxis may be manifested in tasks such as difficulty managing money, planning ahead, organizing and finding things in their room, and time management.

In adulthood, dyspraxia may limit career and avocational choices. Dysfunction in both academic and motor realms is likely to influence future roles and feelings of competence, impeding the ability to explore various available options. Adults identified as very clumsy as children had jobs requiring less manual dexterity than peers (Knuckey & Gubbay, 1983), reported lower quality of life and life satisfaction than typical peers (Hill, Brown, & Sorgardt, 2011; Kirby, Williams, Thomas, & Hill, 2013), and reported several health-related problems including high levels of anxiety and depressive symptoms.

Lastly, certain functional activities present particular challenges for adolescents and adults with DCD. Cantell and colleagues (1994) found that adolescents with motor coordination problems had fewer hobbies than peers and were less likely to engage in sports (Hay & Missiuna, 1998). Daily living skills may be impacted as well, but driving presents the greatest difficulty. Fewer adults with DCD learn to drive compared with those without the disorder, and those who did drive showed difficulties with distance estimation and parking (Kirby et al., 2011), regulating speed while driving, and in coping with distractions (de Oliveira & Wann, 2011).

Behavioral and Social-Emotional Characteristics of Children with Dyspraxia

Many children with dyspraxia are aware of what they can and cannot do and avoid difficult situations. Shaw, Levine, and Belfer (1982) found children with learning disabilities and poor motor coordination had more problems with self-esteem than did children with learning disabilities and no motor problems. They named this phenomenon “developmental double jeopardy.” Stephenson and Chesson (2008) conducted a survey of individuals seen 6 years prior for motor problems. Of the 35 respondents, 28 (80%) reported that motor problems persisted, with 22 of 28 also reporting behavioral and emotional problems. Of the seven children without persisting motor difficulties, only one reported social and emotional problems. Interviews with 12 parents of children from the study described their child as having emotional problems, manifested through anger, frustration, unhappiness, distress, depression, low self-esteem, embarrassment, and shyness. "Opting out" behaviors were described by most mothers. Further, mood disorders frequently accompany DCD. Higher levels of self- and parent-reported depression are seen in children with DCD, especially when the child is a victim of bullying (Lingam et al., 2012). Many studies have suggested higher levels of anxiety and lower levels of self-worth (Lingam et al., 2012; Pearsall-Jones, Piek, & Rigoli, 2011; Pratt & Hill, 2011). Poulsen and colleagues (2007) found children with DCD reported higher levels of loneliness and lower participation in all group activities, whether structured (team sports) or unstructured (informal outdoor play). Moreover, the extent of the child's incoordination related to his or her loneliness. In a large prospective cohort, Lingam, Golding, and Jongmans (2010) found that children with DCD were more likely than their peers to have difficulty making and maintaining friendships. Engel-Yeger (2015) further reported that children and adolescents with DCD have lower levels of participation in home, school, and community settings, and Zwicker, Harris, and colleagues (2013) found that lack of skill in motor performance often leads to poor self-concept, limited social participation, and reduced quality of life.

Cognitive and Executive Function

"As movement assumes meaning, the child learns to motor plan or how to *cortically* direct his movements" (Ayres, 1972b, p. 170, italics added). Although Ayres (1972b) emphasized the roles of sensory processing and body scheme in motor planning, she also stressed the importance of cortical and subcortical processing and indicated that the brain required a variety of information to plan actions. In regards to cortical functions, the relationship of intelligence to dyspraxia has been the source of considerable disagreement. Historically, children with dyspraxia were identified as having normal intelligence with the single most important diagnostic criterion for dyspraxia being poor visual-spatial ability and a significantly lower (less than standard deviation [SD]) performance than verbal IQ score (Gubbay, 1985). Similarly, Smits-Engelsman and Hill (2012) found that only 19% of variance in motor performance scores was explained by IQ scores in children with varying degrees of intellectual ability and that 26% of children with intellectual delays had no motor deficits. They determined that although lower IQ scores were more often associated with lower motor performance, there remained a considerable separation between cognitive ability and motor skill.

This separation is echoed in the *ICD-10:2010* (WHO, 2010), which specifies that the disorder of motor coordination cannot be explained by intellectual disability. In the *DSM-5* (American Psychiatric Association, 2013), it is indicated that a diagnosis of DCD should be made only when a child's motor skills are significantly lower than his or her cognitive skills. Thus, when delays in motor planning are consistent with intellectual development, the child would not be diagnosed with dyspraxia. Furthermore, care must be taken to differentiate delays in motor skill development or execution from poor motor planning. Children with cognitive and intellectual impairments would be considered to have dyspraxia only when their motor deficits are caused by poor motor planning, not simply poor execution, and when their motor planning is significantly poorer than their performance in other areas of cognition.

Executive functioning skills also may play a role in ideation, planning, and monitoring of motor performance. Studies examining motor performance and executive functioning skills in typically developing children have proposed several underlying processes of forward planning, response inhibition, and working memory common to motor performance; and executive skills related to planning, monitoring, and the detection and correction of errors (Livesey, Keen, Rouse, & White 2006; Roebers & Kauer, 2009). Numerous studies suggest that executive functioning skills such as working memory (I. C. Chen, Tsai, Hsu, Ma, & Lai, 2013), verbal fluency, attention, decision-making, problem-solving, and planning are related to motor performance (Hartman, Houwen, Scherder, & Visscher, 2010). Wassenberg and colleagues (2005) found that overall motor performance correlated with general cognitive skills when tests with a motor component were included but did not correlate when the motor-related tests were removed. They found specific cognitive tests of working memory, verbal fluency, and visual-motor integration were related to motor performance, independent of attention, and that these relationships had been previously identified in children with DCD, ADHD, and dyslexia (Hamilton, 2002; Pitcher, Piek, & Hay, 2003; Viholainen, Ahonen, Cantell, Lyytinen, & Lyytinen, 2002). May-Benson (2005) examined characteristics of dyspraxic children with and without ideational difficulties in comparison with typical peers. She found significant differences between all groups on measures of attention and behavior, with children with ideational problems performing worse than those in other groups. On tests of executive planning and fluency, children with dyspraxia but no ideational problems performed more poorly with tasks related to fluency than typical peers and children with ideational difficulties.

HERE'S THE POINT

- Dyspraxia in very young children may be related to difficulties with early developmental motor challenges, delayed development of self-care skills, decreased play skills, speech impairments, and a variety of social-emotional difficulties.
- Dyspraxia and DCD in school-aged children may be related to poor handwriting, decreased participation in sports, difficulties in school, and low self-esteem.
- Dyspraxia and DCD in adolescents and adults may be related to difficulties driving, instrumental activities of daily living (IADLs), maintaining employment, and mental health concerns such as anxiety and depression.

The Intervention Process

The evaluation process—observations in context, interview, clinical observations, and the results of standardized assessments such as the SIPT—provides critical evidence for determining if SI dysfunction is impairing a child's everyday performance. Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests), Chapter 9 (Using Clinical Observations within the Evaluation Process), and Chapter 10 (Assessing Sensory Integrative Dysfunction without the SIPT) address evaluation of sensory integrative disorders. Practitioners, in collaboration with the children with whom they work, caregivers, and teachers, develop a plan for intervention. In this section, SI theory, along with other theories of motor behavior, are used as a framework for interventions that facilitate the development of praxis.

Sensory Integration Principles for Praxis Intervention

SI is not a method by which practitioners *do something to* clients. Rather, practitioners observe how the children with whom they work respond to sensation and cues, interact with significant persons and objects, and adapt to changing environmental demands. Practitioners then create sensory-rich environments that entice their clients to attempt new skills, adapt in new ways, and master appropriate challenges. Intervention involves challenges that lead to improved organization of brain and behavior. Chapter 12 (The Art of Therapy) and Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory) provide considerable detail about using SI theory to address specific aspects of practic dysfunction. The Ayres Sensory Integration© Fidelity Measure (ASIFM) is presented in Chapter 14 (Distilling Sensory Integration Theory for Use: Making Sense of the Complexity). There the structural and process elements that characterize a sensory integrative treatment session are delineated. Several key intervention principles promoted by Ayres are especially important when addressing praxis concerns and are highlighted here. They include:

1. Provision of sensory inputs for specific praxis deficits through active participation in sensorimotor activities
2. Child direction of activity choice
3. Creation of the just-right challenge
4. Facilitation of an adaptive response

Sensory foundations for praxis have been discussed previously. This information is translated to intervention activities to facilitate optimal responses to intervention depending on assessment of the individual's praxis problems. For instance, individuals who present with somatodyspraxia will benefit most from engaging in activities that provide deep touch tactile and heavy work proprioception sensory inputs. These sensory inputs facilitate development of body scheme, which is needed for praxis. These activities are in contrast to the vestibular-proprioceptive activities that best facilitate individuals who present with BIS problems. Individuals with this type of problem benefit from activities that provide strong movement inputs in conjunction with postural and eye-hand coordination demands.

Praxis intervention requires that the child initiate, plan, and execute motor actions so that the SI intervention is child-directed. Ayres (1972b, 1985) also emphasized that an important role of the therapist was to set up the environment so it provided a challenge that was just right. This creation of the just-right challenge in activities requires much skill on the part of the therapist. When a just-right activity is presented, the child will want to engage in the activity and will be successful in doing so, thus producing adaptive responses to the environment.

Ayres (1972b) described the adaptive response as central to praxis intervention. Adaptive responses are purposeful actions directed toward a goal that is successfully achieved, and the production of adaptive responses is thought to be inherently organizing for the brain. Ayres (1972b, 1985) further emphasized that SI intervention was a transaction among client, task, and environment. Although praxis enables effective transactions (Ayres, 1985), the environment guides performance by determining its parameters (E. J. Gibson, 1988). As the environment changes, so must the client's actions (Franchak & Adolph, 2014) (see Fig. 5-4).

FIGURE 5-4 An environment that offers equipment with many affordances can be motivating to the child and can allow the therapist to structure a just right challenge.

Interventions for Motor Planning and Motor Coordination

In addition to treating dyspraxia from an SI approach as described previously, several motor behavior intervention theories have emerged that provide useful information that may augment and enhance traditional sensory integrative-based interventions for the development of motor planning abilities. These theories can be divided into three categories:

1. Motor learning and motor control
2. Contextual and ecological approaches
3. Mental practice approaches

Motor Learning and Motor Control Approaches

Motor learning refers to the acquisition or modification of movement, whereas **motor control** is concerned with the regulation and refinement of movement that has already been acquired (Shumway-Cook & Woollacott, 2011). Current motor learning theories support a model of flexible, changing behavior in response to the demands of the situation, which are similar to the adaptive response that is so integral to SI-based intervention (Ullsperger, Danielmeier, & Jocham, 2014). Both perspectives emphasize that actions reflect an interaction among the person, task, and environment. Within the person, multiple systems (i.e., perceptual, cognitive, and motor) interact with unique tasks in the contexts in which they occur, requiring both feedforward and feedback control to achieve a goal (Shumway-Cook & Woollacott, 2011). Within these models, considerable emphasis has been placed on both the environment and the individual's interest for engaging with that environment.

Intervention for children with dyspraxia involves creating interesting and challenging tasks that facilitate improved motor planning and skill acquisition. Actions are generated from past experiences that are successful and stored as long-term motor memories. From motor learning and SI perspectives, repetition of motor skills is needed for them to be stored and retrieved in a way that supports skill development (Brooks, 1986). Traditional ideas from motor learning indicate that blocked practice, or the repetition of an action within a concentrated time period, is most beneficial for learning a new skill (Kantak & Winstein, 2012). This suggests that therapists using an SI approach may encourage children to repeat a new motor planning task multiple times within a single therapy session to best store the motor memories from that task for long-term retention (e.g., have a child repeat the activity of crawling through a tunnel, climbing a ladder, and swinging on a trapeze five times).

However, this type of learning does not necessarily increase generalizability of skills. Motor learning is best facilitated when repetition of activities involves variations on previously learned tasks and occurs randomly (i.e., performance of one task followed by a different one) across different time periods (Schmidt & Lee, 2013). Embedding a variety of movements and tasks in novel conditions increases the adaptability of the movement (Soderstrom & Bjork, 2013). This perspective is consistent with an SI approach to treating motor planning, which emphasizes using similar actions while engaged in a variety of activities (e.g., pumping swing and throwing a beanbag or climbing a structure and jumping in a ball pit).

After a child has learned a skill in a therapeutic environment, it generally is necessary to transfer that skill to situations such as home or school. The more closely the demands of the practice environment resemble those of the child's real-life environment, the easier the transfer of skills (Kantak & Winstein, 2012). This may be especially true for individuals who have dyspraxia and who may have difficulty generalizing to new situations. Because of their hypothesized difficulty developing schemas or neuronal models of action that can be generalized, those with dyspraxia may have particular difficulty realizing gains made during intervention in their daily lives (Ayres, 1985; Brooks, 1986). Therapists are especially challenged to find varied and creative ways for facilitating motor learning and motor planning, while selecting tools and materials that are likely to be encountered by the client on a day-to-day basis.

Contextual and Ecological Approaches

Contextual approaches to motor performance are particularly relevant to occupational therapy using an SI approach because active participation in meaningful occupation and the planning and production of adaptive responses are central to SI theory and intervention. Fidler and Fidler (1978) asserted that purposeful activity provided the action–learning experience essential for skill acquisition. Gliner (1985) emphasized the interaction between the individual and the environment (i.e., object and task) rather than the movement itself and suggested that the environment provided meaning and support to the person performing the action. Similarly, King (1978) maintained that adaptive behavior was organized best through active involvement in occupations. She suggested that in doing purposeful tasks, attention was directed toward the object or the goal rather than the movement. Many of the concepts proposed by these early occupational therapists are consistent with current contextual or ecological theory (Rose & Christina, 2006).

Contextual theories of motor behavior, known as **systems theories** or **ecological theories,** have examined perceptual control of action and are focused on the idea that spatial knowledge of the external world is derived from movement experiences associated with vision and memory. One ecological view, known as **action systems theory,** focuses on the functional specificity and meaning of actions and emphasizes the need to study actions within natural contexts (Reed, 1988). From an SI perspective, this means observing children performing in their typical contexts, such as playing on the school playground, because individuals will perform differently in varying environments (i.e., a child may be able to make a basket in his own home basketball hoop but not at the school playground).

Similar to action systems theory, **dynamical systems theory** challenges traditional views that human development proceeds in an orderly and consistent way with little variability in the acquisition of skills. In this theory, motor behavior is described as fluid, highly variable, and dependent on interaction with the surrounding world through the exploration of new contexts (Smith & Thelen, 2003). Similar ideas are presented in the ecological theories of E. J. and J. J. Gibson, whose research coupled action and perception (Adolph & Kretch, 2015). J. J. Gibson (1979) defined *affordances* as reciprocal relationships between a person and the environment that enabled performance of functional tasks. As a child acquires new motor milestones, new opportunities are offered for perceptual discoveries. Environmental interaction, then, is the key to facilitating and fine tuning perception and motor behavior as a basis for further development. In other words, by changing the environment, the occupational therapist using an SI approach can facilitate change in the child's motor planning in a functional way.

Mental Practice Approaches

Mental practice, or imagery of an action, has also been found to have positive influences on motor learning and performance. Using mental practice activates neural areas that are responsible for programming movements and executing a task, regions similar to those engaged when actually performing the action (Malouin, Jackson, & Richards, 2013). Mental practice significantly increases cerebral blood flow to premotor and frontal cortices as well as the SMA, all of which play an important role in planning complex movements performed during practic activities (Madan & Singhal, 2012). Timing, force, and organization of movements was also improved with mental practice, apparently through activation of the cerebellum (D'Angelo & Casali, 2013), thus being a potential method of improving projected action skills. In SI intervention, this approach may also help a child with development of ideation and motor planning skills by consciously imagining what he or she will do during a particular task before actually performing it, thus helping the child generate more effective motor plans.

Intervention for Ideation

Although interventions for motor planning and motor coordination skills are well documented, our understanding of intervention strategies for the ideational aspect of praxis is still in its infancy. However, many strategies associated with action systems and dynamical systems theories have been found clinically to be helpful in promoting ideational skills in children with dyspraxia. Ayres (1972b, 1985) emphasized the importance of using a variety of equipment to design the just-right challenge. Objects and the environment that contains them provide guides for action. Equipment commonly used in intervention based on SI theory provides "affordances" or qualities that promote interaction. By increasing a child's awareness of object and action affordances, the child is able to perceive the meaning of what to do with objects or equipment and is better able to generate ideas of ways to act on that meaning. The child's actions are then guided, in part, by the nature of the equipment and its perceptual characteristics. Schaaf and colleagues (2010) proposed four postulates of change for ideation, which include bridging the child's current activity with similar previous experiences (i.e., "remember we used the bolster swing to climb on here last week"); providing the child with familiar mental images related to the child's actions to promote development of representational abilities needed for ideation (i.e., "you are swinging on the trapeze like a monkey"); encouraging imitation and creative expansion of ideas (i.e., a question such as "I wonder if you could climb up on this?"); and exploration and increased awareness of object affordances (i.e., "How many ways can you think of to use this object?"). In addition to these strategies, the use of cognitive strategies (i.e., questioning, bridging, providing additional information) and mental imagery, in conjunction with facilitation of the ability to recognize and act on affordances, can promote skills for improving ideation for praxis.

Recall the cases of Alyssa and Dalton described earlier in this chapter. Next, intervention for each case is presented to demonstrate and apply the intervention principles and strategies we have discussed for addressing childhood dyspraxia.

PRACTICE WISDOM

The motor performance of children with dyspraxia is enhanced by gross motor play activities rich in proprioceptive sensory input because this input gives them a better sense of how their bodies are moving in space. Examples of such activities include push-and-pull games such as tug-of-war, jumping, climbing, using swings that bounce (have a bungee cord attached), and playing in and with stretchy spandex. Likewise, extracurricular activities or sports that naturally provide a lot of proprioception, including downhill skiing, mountain biking, using a trampoline, and horseback riding, as well as contact sports such as wrestling and football, may be areas where children with dyspraxia find more success than those that involve little proprioceptive sensory input.

CASE STUDY ■ INTERVENTION FOR ALYSSA AND DALTON

Alyssa

Alyssa's evaluation identified poor processing of tactile, vestibular, and proprioceptive sensations. She also had marked difficulty on tests that require motor planning and visual motor coordination. Supplemental observations and assessment also suggested difficulties with generating ideas for motor actions in addition to difficulties planning them. It was concluded that she had dyspraxia involving both gross and fine motor planning that was related to poor sensory processing. It was believed that motor planning difficulties contributed to her poor visual-motor coordination, which affected her handwriting, self-care skills, and play behavior (see Fig. 5-5).

In intervention, the therapist provided Alyssa with opportunities to receive enhanced sensation in the context of meaningful activities. Alyssa initially delighted in opportunities to be contained in small spaces. Climbing into a large cloth bag that was filled with small plastic balls provided an opportunity for her to plan and organize her movement in a simple way and receive enhanced tactile input. The bag became a washing machine as the therapist closed it up and moved it rapidly and vigorously back and forth on the mat. In doing so, the activity provided tactile, proprioceptive, and vestibular input. Alyssa also liked to pretend that she was a bird in a nest, created with a large inner tube lying on the floor and filled with pillows and beanbags; however, she was not able to self-generate play ideas where she actually moved her body through space.

After Alyssa had been in occupational therapy for several weeks, the therapist wanted to involve her in activities that were more demanding. For example, the therapist engaged her in an activity of swinging on a trapeze and letting go to land in a pile of pillows. Although this activity, which involves planning and executing projected action sequences, was initially difficult for Alyssa, the task was graded to provide a just-right challenge. First, the therapist set up the activity so Alyssa could jump from the top of three steps positioned next to the pillows. Then the therapist added the trapeze and Alyssa was able to hold herself on the trapeze and drop into the pillows. Next, the therapist moved the steps three feet away from where Alyssa first jumped into the pillows and then was able to hold the trapeze and jump. Eventually she was able to swing and drop into the pillows. Alyssa was offered the opportunity to try and to repeat (practice) several variations of the activity. As she accomplished the intended goal each time, she developed action plans that allowed her to flexibly meet the changing task demands.

FIGURE 5-5 Children with somatodyspraxia may need to practice activities, such as coloring or handwriting, more than other children in order to achieve success.

Dalton

Dalton's motor problems were milder with sensory processing issues predominantly in vestibular-proprioceptive domains. These difficulties appeared to interfere with adequate postural control, coordinated use of his two body sides, his ability to anticipate body actions, and projecting his body through space. In addition, his distractibility and decreased attention, which seemed to be separate from his sensory integrative dysfunction, prevented him from focusing and interfered with his ability to acquire motor skills. The therapist gave Dalton many opportunities for dynamic and intense movement, particularly through the use of suspended equipment.

Dalton was eager to try different swings and found he could control the speed of the glider to crash into towers he had built with soft foam blocks. The therapist created several challenges to his postural reactions, and he took great pride in his ability to stay on the swing even when moving through wide excursions. He dubbed the bolster swing "the bucking bronco." As he held onto overhead ropes, the therapist moved the bolster in various directions with increasing vigor, and he adapted his reactions to accommodate the increased demands. Visual-spatial demands are also inherent in such tasks because they involve movement in relation to objects and the environment (see Fig. 5-6).

As therapy proceeded for both children, a broader view of dyspraxia was taken and "cognitive strategies" were used, such as visual direction, which involves reminding clients to look at a particular place or object, or demonstrating the activity so as to provide clients with a visual model of how the activity is performed. For example, when Alyssa wanted to climb to the top of a playground jungle gym, an alternate route was indicated for her, and she was given a cue to look up to the top of the structure. Another cognitive strategy, verbal mediation and monitoring, involves requesting that the child verbalize what is to be done or what has been done. Alyssa's verbal skills were very good, and it was especially helpful to her to build on an existing strength as she engaged in motor challenges. For Dalton, whose distractibility and short attention span were problematic, verbal mediation helped him focus on a specific goal and consider the appropriate sequence of actions. Moreover, when both children were asked to describe what they wanted to do, they had the opportunity to formulate a cognitive representation of the action of climbing to the top of the jungle gym or kicking the ball into the net.

For someone with BIS deficits such as Dalton, whose sensory integrative deficits are relatively mild, imagining actions (mental practice) might be another avenue to pursue in intervention. Before engaging in a task, Dalton could be asked to close his eyes and imagine that he is doing the task. This could be followed by the actual performance of the action. Adding the reinforcement of verbal feedback based on his actions (e.g., saying "I like the way you reached across your body when you picked that up" rather than just saying "good job") or, even better, having Dalton identify the order and success of events could be included. The incorporation of cognitive components (i.e., visual direction and verbal mediation, focusing on the activity as a whole rather than on the components, visualization of the act), together with enhanced tactile, vestibular, proprioceptive, and visual sensation, facilitate the development of ideational skills and can improve planning and production of movement. Both Alyssa and Dalton could reap the benefits of combined sensation and cognitive processes that together enhanced their ability to plan "what to do" and "how to do it."

FIGURE 5-6 A whale swing may be a good activity for a child with BIS as it provides vestibular and proprioceptive inputs while coordinating the upper and lower body.

HERE'S THE POINT

- SI theory provides a framework to treat praxis deficits.
- Other theories of motor behavior offer additional insight into interventions to facilitate the development of praxis.

Evidence for Interventions for Dyspraxia

Outcomes of intervention for praxis deficits should reflect changes in participation and role performance, development of competence in activities, improved social interactions, and improved self-esteem and self-worth. May-Benson and Koomar (2010) completed a systematic review of the efficacy evidence for occupational therapy using an SI approach with children with problems processing and integrating sensory information that specifically included children with praxis deficits. They found 10 of 14 studies examining motor outcomes resulted in positive gains in children with praxis problems, with additional improvements noted in areas of sensory processing, behavioral regulation, academic skills, and occupational performance. A related systematic review by Polatajko and Cantin (2010) found sensorimotor interventions with children with autism and DCD diagnoses also resulted in positive gains in areas of neuromotor functioning, sensory organization, and decreased falls and suggested that sensorimotor-based interventions may be most effective in improving body function and impairment level difficulties. Further, they found that performance-oriented approaches such as direct skills teaching and cognitive-based approaches were most effective in improving specific activity performance and participation.

Evidence for the effectiveness of interventions for praxis deficits in children is limited although additional literature exists for children with DCD. Three meta-analyses examined interventions for children with DCD. Pless and Carlsson (2000) included 13 studies of motor interventions for children with DCD or equivalent conditions and concluded that the most effective motor interventions were with children older than 5 years of age, used a specific skill development approach, included a home program, and were conducted at least three to five times per week. A meta-analysis on the use of cognitive (top-down) approaches with children with DCD found these children demonstrated improved skill transfer with the use of cognitive-oriented approaches (H. F. Chen, Tickle-Degnen, & Cermak, 2003). A final meta-analysis of 20 studies on motor performance interventions in children with DCD found that intervention (task-oriented and traditional motor-training-based occupational and physical therapy approaches) was better than no intervention for motor deficits with an effect size of $d = 0.56$ (Smits-Engelsman et al., 2013).

Summary and Conclusions

This chapter has addressed the very complex issues that surround praxis. Sensation and movement are intricately intertwined in the CNS, and a growing interest in disorders of movement has produced a rich body of work around motor behavior. However, praxis involves more than movement; cognitive processes also play an important role. Intervention for practic disorders is challenging and exciting. Finally, research suggests that both sensory-motor and cognitive-based interventions may be effective for children with praxis deficits but that each type of intervention may target different types of outcomes.

Where Can I Find More?

Biggs, V. (2014). *Caged in chaos: A dyspraxic guide to breaking free.* London, UK: Jessica Kingsley Publishers. A practical guide written by a teenager with dyspraxia with down to earth advice on a range of practical issues and daily living skills.

Cermak, S., & Larkin, D. (2002). *Developmental coordination disorder: A comprehensive textbook covering all aspects related to DCD and dyspraxia.* Albany, NY: Delmar Thompson Learning.

Dixon, G. (2017). *Discover yourself: A book for children with dyspraxia.* Aimed at 7- to 10-year-olds with dyspraxia, this book has been illustrated by children. Hitchin, Hertz UK: Dyspraxia Foundation. http://dyspraxiafoundation.org.uk

Kirby, A. (2017). *Dyspraxia—Developmental co-ordination disorder.* Explains causes, symptoms, and diagnostic procedures with positive coping strategies, and how to deal with problems faced by teenagers and adults who have dyspraxia. Hitchin, Hertz UK: Dyspraxia Foundation. http://dyspraxiafoundation.org.uk

Resources available from Dyspraxia Foundation USA: http://www.dyspraxiausa.org

Resources available from the Spiral Foundation: https://thespiralfoundation.org

References

Abu-Dahab, S. M. N., Holm, M. B., Rogers, J. C., Skidmore, E., & Minshew, N. J. (2013). Motor and tactile-perceptual skill differences between individuals with high-functioning autism and typically developing individuals ages 5–21. *Journal of Autism and Developmental Disorders, 43*(10), 2241–2248.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Adolph, K., & Kretch, K. (2015). Gibson's theory of perceptual learning. *International Encyclopedia of the Social & Behavioral Sciences, 2nd Ed.*, *10*, 127–134.

Asonitou, K., Koutsouki, D., Kourtessis, T., & Charitou, S. (2012). Motor and cognitive performance differences between children with and without developmental coordination disorder (DCD). *Research in Developmental Disabilities*, *33*(4), 996–1005.

Ayres, A. J. (1965). Patterns of perceptual motor dysfunction in children: A factor-analytic study. *Perceptual and Motor Skills*, *20*, 335–368.

Ayres, A. J. (1966). Interrelations among perceptual motor abilities in a group of normal children. *American Journal of Occupational Therapy*, *20*, 288–292.

Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. *American Journal of Occupational Therapy*, *25*, 329–334.

Ayres, A. J. (1972a). Improving academic scores through sensory integration. *Journal of Learning Disabilities*, *5*, 338–343.

Ayres, A. J. (1972b). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy*, *31*, 362–366.

Ayres, A. J. (1985). *Developmental dyspraxia and adult onset apraxia*. Torrance, CA: Sensory Integration International.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests*. Los Angeles, CA: Western Psychological.

Ayres, A. J., Mailloux, Z., & Wendler, C. L. (1987). Developmental dyspraxia: Is it a unitary function? *Occupational Therapy Journal of Research*, *7*, 93–110.

Bart, O., Jarus, T., Erez, Y., & Rosenberg, L. (2011). How do young children with DCD participate and enjoy daily activities? *Research in Developmental Disabilities*, *32*(4), 1317–1322.

Beets, I. A., Macé, M., Meesen, R. L., Cuypers, K., Levin, O., & Swinnen, S. P. (2012). Active versus passive training of a complex bimanual task: Is prescriptive proprioceptive information sufficient for inducing motor learning? *PloS One*, *7*(5), e37687.

Blanche, E. I. (2010). *Observations based on sensory integration theory*. Torrance, CA: Pediatric Therapy Network.

Blanche, E. I., Bodison, S., Chang, M. C., & Reinoso, G. (2012). Development of the Comprehensive Observations of Proprioception (COP): Validity, reliability, and factor analysis. *American Journal of Occupational Therapy*, *66*(6), 691–698.

Brooks, V. B. (1986). How does the limbic system assist motor learning? A limbic comparator hypothesis. *Brain Behavior Evolution*, *29*, 29–53.

Brossard-Racine, M., Shevell, M., Snider, S., Belanger, S. A., & Majnemer, A. (2012). Motor skills of children newly diagnosed with attention deficit hyperactivity disorder prior to and following treatment with stimulant medication. *Research in Developmental Disabilities*, *33*, 2080–2087.

Bruininks, R. H., & Bruininks, B. D. (2005). *Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)*. San Antonio, TX: Pearson.

Cantell, M. H., Smyth, M. M., & Ahonen, T. P. (1994). Clumsiness in adolescence: Educational, motor, and social outcomes of motor delay detected at 5 years. *Adapted Physical Activity Quarterly*, *11*(2), 115–129.

Cermak, S. A. (2011). Reflections on 25 years of dyspraxia research. *Ayres Dyspraxia Monograph, 25 Year edition*. Torrance, CA: Pediatric Therapy Network.

Cermak, S. A., Katz, N., Weintraub, N., Steinhart, S., Raz-Silbiger, S., Munoz, M., & Lifshitz, N. (2015). Participation in physical activity, fitness, and risk for obesity in children with developmental coordination disorder: A cross-cultural study. *Occupational Therapy International*, *22*(4), 163–173. doi:10.1002/oti.1393

Chen, H. F., Tickle-Degnen, L., & Cermak, C. (2003). The treatment effectiveness of top-down approaches for children with developmental coordination disorder: A meta-analysis. *Journal of Occupational Therapy Association, R.O.C.*, *21*, 16–28.

Chen, I. C., Tsai, P. L., Hsu, Y. W., Ma, H. I., & Lai, H. A. (2013). Everyday memory in children with developmental coordination disorder. *Research in Developmental Disabilities*, *34*(1), 687–694. doi:10.1016/j.ridd.2012.09.012

Chen, J. L., Penhune, V. B., & Zatorre, R. J. (2008). Moving on time: Brain network for auditory-motor synchronization is modulated by rhythm complexity and musical training. *Journal of Cognitive Neuroscience*, *20*(2), 226–239.

Chen, J. L., Rae, C., & Watkins, K. E. (2012). Learning to play a melody: An fMRI study examining the formation of auditory-motor associations. *Neuroimage*, *59*(2), 1200–1208.

Cousins, M., & Smyth, M. M. (2003). Developmental coordination impairments in adulthood. *Human Movement Science*, *22*(4), 433–459. doi:10.1016/j.humov.2003.09.003

D'Angelo, E., & Casali, S. (2013). Seeking a unified framework for cerebellar function and dysfunction: From circuit operations to cognition. *Frontiers in Neural Circuits*, *6*(116), 1–23.

Daprati, E., Sirigu, A., & Nico, D. (2010). Body and movement: Consciousness in the parietal lobes. *Neuropsychologia*, *48*(3), 756–762. doi:10.1016/j.neuropsychologia.2009.10.008

de Oliveira, R. F., & Wann, J. P. (2011). Driving skills of young adults with developmental coordination disorder: Regulating speed and coping with distraction. *Research in Developmental Disabilities*, *32*(4), 1301–1308.

Dijkerman, H. C., & de Haan, E. H. (2007). Somatosensory processes subserving perception and action. *Behavior and Brain Science*, *30*(2), 189–201. doi: 10.1017/S0140525X07001392

Dionne, J. K., Legon, W., & Staines, W. R. (2013). Crossmodal influences on early somatosensory processing: Interaction of vision, touch, and task-relevance. *Experimental Brain Research*, *226*(4), 503–512.

Dunn, W. (2013). *The Sensory Profile—Second ed. Examiner's manual*. San Antonio, TX: The Psychological Corporation.

Dziuk, M. A., Gidley Larson, J. C., Apostu, A., Mahone, E. M., Denckla, M. B., & Mostofsky, S. H. (2007). Dyspraxia in autism: Association with motor, social, and communicative deficits. *Developmental Medicine and Child Neurology*, *49*(10), 734–739. doi:10.1111/j.1469-8749.2007.00734.x

Engel-Yeger, B. (2015). Developmental coordination and participation. In J. Cairney (Ed.), *Developmental coordination disorder and its consequences*. Toronto: University of Toronto Press.

Esposito, G., & Venuti, P. (2008). Analysis of toddlers' gait after six months of independent walking to identify autism: A preliminary study 1. *Perceptual and Motor Skills*, *106*(1), 259–269.

Exner, C. E. (1992). In-hand manipulation skills. In J. Case-Smith & C. Pehoski (Eds.), *Development of hand skills in the child*. Rockville, MD: American Occupational Therapy Association.

Fidler, G. S., & Fidler, J. W. (1978). Doing and becoming: Purposeful action and self-actualization. *American Journal of Occupational Therapy*, *32*, 305–310.

Foundas, A. L. (2013). Apraxia: Neural mechanisms and functional recovery. *Handbook of Clinical Neurology*, *110*, 335–345.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Developmental Disorders*, *40*(10), 1227–1240. doi:10.1007/s10803-010-0981-3

Franchak, J., & Adolph, K. (2014). Affordances as probabilistic functions: Implications for development, perception, and decisions for action. *Ecological Psychology*, *26*, 109–124.

Fuster, J. M. (2008). *The prefrontal cortex* (4th ed.). Amsterdam, Netherlands: Elsevier.

Gee, B. M., Devine, N., Werth, A., & Phan, V. (2013). Paediatric occupational therapists' use of sound-based interventions: A survey study. *Occupational Therapy International*, *20*(3), 155–162.

Gentsch, A., Weber, A., Synofzik, M., Vosgerau, G., & Schütz-Bosbach, S. (2016). Towards a common framework of grounded action cognition: Relating motor control, perception and cognition. *Cognition*, *146*, 81–89.

Gibson, E. J. (1988). Exploratory behavior in the development of perceiving, acting and the acquiring of knowledge. *Annual Review of Psychology*, *39*, 1–41.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton-Mifflin.

Gillberg, C. (2003). Deficits in attention, motor control, and perception: A brief review. *Archives of Child Development*, *88*, 904–910.

Gliner, J. A. (1985). Purposeful activity in motor learning theory: An event approach to motor skill acquisition. *American Journal of Occupational Therapy*, *39*, 28–34.

Goldstand, S., Gevir, D., Cermak, S., & Bissell, J. (2013). *Here's how I write: A child's self assessment and handwriting tool*. Framingham, MA: Therapro.

Gubbay, S. S. (1975). *The clumsy child*. New York, NY: W. B. Saunders.

Gubbay, S. S. (1985). Clumsiness. In P. J. Vinken, G. W. Bruyn, & H. L. Klawans (Eds.), *Handbook of clinical neurology (Rev. series)*. New York, NY: Elsevier Science.

Hamilton, S. S. (2002). Evaluation of clumsiness in children. *American Family Physician*, *66*, 1435–1440.

Hardwick, R. M., Rottschy, C., Miall, R. C., & Eickhoff, S. B. (2013). A quantitative meta analysis and review of motor learning in the human brain. *NeuroImage*, *67*, 283–297.

Harrington, D. L., Rao, S. M., Haaland, K. Y., Bobholz, J. A., Mayer, A. B., & Binderix, J. R. (2000). Ideomotor apraxia and cerebral dominance for motor control. *Cognitive Brain Research*, *3*, 95–100.

Hartman, E., Houwen, S., Scherder, E., & Visscher, C. (2010). On the relationship between motor performance and executive functioning in children with intellectual disabilities. *Journal of Intellectual Disability Research*, *54*(5), 468–477.

Hay, J., & Missiuna, C. (1998). Motor proficiency in children reporting low levels of participation in physical activity. *Canadian Journal of Occupational Therapy*, *65*(2), 64–71.

Hellgren, L., Gillberg, C., Gillberg, I. C., & Enerkskog, I. (1993). Children with deficits in attention, motor control, and perception (DAMP) almost grown up: General health at 16 years. *Developmental Medicine and Child Neurology*, *35*, 881–892.

Henderson, S., Sugden, D., & Barnett, A. (2007). *Movement Assessment Battery for Children—Second Edition (MABC-2)*. San Antonio, TX: Pearson.

Hill, E. L., Brown, D., & Sorgardt, K. S. (2011). A preliminary investigation of quality of life satisfaction reports in emerging adults with and without developmental coordination disorder. *Journal of Adult Development*, *18*(3), 130–134.

Hilton, C. L., Zhang, Y., White, M. R., Klohr, C. L., & Constantino, J. (2012). Motor impairment in sibling pairs concordant and discordant for autism spectrum disorders. *Autism*, *16*, 430–441. doi:10.1177/1362361311423018

Itō, M. (2012). *Cerebellum: The brain for an implicit self*. Upper Saddle River, NJ: FT Press.

Ivey, C. K., Lane, S. J., & May-Benson, T. A. (2014). Interrater reliability and developmental norms in preschoolers for the Motor Planning Maze Assessment (MPMA). *American Journal of Occupational Therapy*, *68*(5), 539–545.

Jeannerod, M., & Decety, J. (1995). Mental motor imagery: A window into the representational stages of action. *Current Opinion in Neurobiology*, *5*(6), 727–732.

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth, A. (2012). *Principles of neural science* (5th ed.). New York, NY: McGraw-Hill Professional.

Kantak, S. S., & Winstein, C. J. (2012). Learning-performance distinction and memory processes for motor skills: A focused review and perspective. *Behavioral Brain Research*, *228*(1), 219–231.

Kawar, M. (2005). A sensory integration context for vision. In M. Gentile (Ed.), *Functional visual behavior in children* (2nd ed., pp. 87–144). Bethesda, MD: American Occupational Therapy Association Press.

Kennedy-Behr, A., Rodger, S., & Mickan, S. (2011). Physical and social play of preschool children with and without coordination difficulties: Preliminary findings. *British Journal of Occupational Therapy*, *74*(7), 348–354.

Kiernan, J., & Rajakumar, R. (2013). *Barr's the human nervous system: An anatomical viewpoint*. Philadelphia, PA: Lippincott Williams & Wilkins.

King, B. R., Kagerer, F. A., Harring, J. R., Contreras-Vidal, J. L., & Clark, J. E. (2011). Multisensory adaptation of spatial-to-motor transformations in children with developmental coordination disorder. *Experimental Brain Research*, *212*(2), 257–265.

King, L. J. (1978). Toward a science of adaptive responses. *American Journal of Occupational Therapy*, *32*, 429–437.

Kirby, A., Edwards, L., & Sugden, D. (2011). Emerging adulthood in developmental co-ordination disorder: Parent and young adult perspectives. *Research in Developmental Disabilities*, *32*(4), 1351–1360. doi:10.1016/j.ridd.2011.01.041

Kirby, A., Sugden, D., & Purcell, C. (2014). Diagnosing developmental coordination disorders (Review). *Archives of Diseases of Childhood*, *99*, 292–296.

Kirby, A., Williams, N., Thomas, M., & Hill, E. L. (2013). Self-reported mood, general health, wellbeing and employment status in adults with suspected DCD. *Research in Developmental Disabilities*, *34*(4), 1357–1364. doi:10.1016/j.ridd.2013.01.003

Knuckey, N., & Gubbay, S. S. (1983). Clumsy children: A prognostic study. *Australian Pediatric Journal*, *19*, 9–13.

Koziol, L. F., Budding, D., Andreasen, N., D'Arrigo, S., Bulgheroni, S., Imamizu, H., . . . Yamazaki, T. (2014). Consensus paper: The cerebellum's role in movement and cognition. *Cerebellum*, *13*(1), 151–177. doi:10.1007/s12311-013-0511-x

Lai, J. S., Fisher, A., Magalhães, L., & Bundy, A. (1996). Construct validity of the Sensory Integration and Praxis Tests. *Occupational Therapy Journal of Research*, *16*, 75–97.

Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry*, *47*(6), 629–638. doi:10.1111/j.1469-7610.2006.01531.x

Landgren, M., Pettersen, R., Kjellman, B., & Gillberg, C. (1996). ADHD, DAMP and other neurodevelopmental disorders in 6-year-old children: Epidemiology and co-morbidity. *Developmental Medicine and Child Neurology*, *38*, 891–906.

Lane, S. J., Ivey, C. K., & May-Benson, T. A. (2014). Test of Ideational Praxis (TIP): Preliminary findings and interrater and test–retest reliability with preschoolers. *American Journal of Occupational Therapy*, *68*(5), 555–561.

Levine, M. D. (1987). Motor implementation. In M. D. Levine (Ed.), *Developmental variation and learning disorders* (pp. 208–239). Cambridge, MA: Educators Publishing Service.

Levine, M. D. (2003). *The myth of laziness*. New York, NY: Simon and Schuster.

Lin, C. K., Wu, H. M., Lin, C. H., Wu, Y. Y., Wu, P. F., Kuo, B. C., & Yeung, K. T. (2012). A small sample test of the factor structure of postural movement and bilateral motor integration using structural equation modeling. *Perceptual and Motor Skills*, *115*(2), 544–557.

Lingam, R., Golding, J., & Jongmans, M. J. (2010). The association between developmental coordination disorder and other developmental traits. *Pediatrics*, *126*(1), e1109–e1118.

Lingam, R., Jongmans, M. J., Ellis, M., Hunt, L. P., Golding, J., & Emond, A. (2012). Mental health difficulties in children with developmental coordination disorder. *Pediatrics*, *129*(4), e882–e891. doi:10.1542/peds.2011-1556

Livesey, D., Keen, J., Rouse, J., & White, F. (2006). The relationship between measures of executive function, motor performance and externalising behaviour in 5- and 6-year-old children. *Human Movement Science*, *25*(1), 50–64. doi:10.1016/j.humov.2005.10.008

Lohse, K. R., Wadden, K., Boyd, L. A., & Hodges, N. J. (2014). Motor skill acquisition across short and long time scales: A meta-analysis of neuroimaging data. *Neuropsychologia*, *59*, 130–141.

Lopez, C., Schreyer, H. M., Preuss, N., & Mast, F. W. (2012). Vestibular stimulation modifies the body schema. *Neuropsychologia*, *50*(8), 1830–1837.

Losse, A., Henderson, S. E., Elliman, D., Hall, D., Knight, E., & Jongmans, M. (1991). Clumsiness in children—do they grow out of it? A 10-year follow-up study. *Developmental Medicine and Child Neurology*, *33*(1), 55–68.

Lundy-Ekman, L. (2013). *Neuroscience fundamentals for rehabilitation* (4th ed.). Philadelphia, PA: W.B. Saunders.

Luria, A. R. (1963). *Restoration of function after brain injury*. New York NY: Pergamon.

Luria, A. R. (1980). *Higher cortical functions in man*. New York, NY: Basic.

MacNeil, L. K., & Mostofsky, S. H. (2012). Specificity of dyspraxia in children with autism. *Neuropsychology*, *26*(2), 165–171. doi:10.1037/a0026955

Madan, C. R., & Singhal, A. (2012). Using actions to enhance memory: Effects of enactment, gestures, and exercise on human memory. *Frontiers in Psychology*, *3*(507), 1–4.

Magalhães, L. C., Cardoso, A. A., & Missiuna, C. (2011). Activities and participation in children with developmental coordination disorder: A systematic review. *Research in Developmental Disabilities*, *32*(4), 1309–1316. doi:10.1016/j.ridd.2011.01.029

Mailloux, Z., Mulligan, S., Roley, S. S., Blanche, E., Cermak, S., Coleman, G. G., . . . Lane, C. J. (2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy*, *65*(2), 143–151.

Majernik, J., Molcan, M., & Majernikova, Z. (2010, January). Evaluation of posture stability in patients with vestibular diseases. In *Applied Machine Intelligence and Informatics (SAMI), 2010 IEEE 8th International Symposium on Applied Machine Intelligence and Informatics* (pp. 271–274). IEEE.

Malkani, R., & Zadikoff, C. (2011). The apraxias in movement disorders. In N. G. Gálvez-Jiménez & P. Tuite (Eds.), *Uncommon causes of movement disorders* (pp. 35–45). Cambridge, UK: Cambridge University Press.

Malouin, F., Jackson, P. L., & Richards, C. L. (2013). Towards the integration of mental practice in rehabilitation programs. A critical review. *Frontiers of Human Neuroscience*, *7*, 576. doi:10.3389/fnhum.2013.00576

Mandich, A. D., Polatajko, H. J., & Rodger, S. (2003). Rites of passage: Understanding participation of children with developmental coordination disorder. *Human Movement Science*, *22*(4-5), 583–95. doi:S0167945703000733

May-Benson, T. A. (2000). Preliminary validity evidence for the Test of Ideational Praxis. Unpublished manuscript.

May-Benson, T. (2001). A theoretical model of ideation. In E. Blanche, R. Schaaf, & S. Smith Roley (Eds.), *Understanding the nature of sensory integration with diverse populations*. San Antonio, TX: Therapy Skill Builders.

May-Benson, T. A. (2005). Examining ideational abilities in children with dyspraxia. Doctoral dissertation. Boston University. Ann Arbor, MI: ProQuest.

May-Benson, T. A., & Cermak, S. A. (2007). Development of an assessment for ideational praxis. *American Journal of Occupational Therapy*, *61*(2), 148–153.

May-Benson, T. A., & Koomar, J. A. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy*, *64*(3), 403–414.

May-Benson, T. A., Koomar, J. A., & Teasdale, A. (2009). Incidence of pre-, peri-, and post-natal birth and developmental problems of children with sensory processing disorder and children with autism spectrum disorder. *Frontiers of Integrative Neuroscience*, *3*(31), doi:10.3389/neuro.07.031.2009

McHale, K., & Cermak, S. (1992). Fine motor activities in elementary school: Preliminary findings and provisional implications for children with fine motor problems. *American Journal of Occupational Therapy*, *46*, 898–903.

Medina, J., & Coslett, H. B. (2010). From maps to form to space: Touch and the body schema. *Neuropsychologia*, *48*(3), 645–654. doi:10.1016/j.neuropsychologia.2009.08.017

Miller, L. J., & Schoen, S. A. (2012). *The Sensory Processing Scales Inventory (SenSI)*. Greenwood Village, CO: Developmental Technologies.

Miller-Kuhaneck, H., & Watling, R. (2010). *Autism: A comprehensive occupational therapy approach* (3rd ed.). Bethesda, MD: AOTA Press.

Morris, M. K. (1997). Developmental dyspraxia. In L. J. G. Rothi & K. M. Heilman (Eds.), *Apraxia: The neuropsychology of action* (pp. 245–268). Hove, England: Psychology Press.

Mostofsky, S. H., Dubey, P., Jerath, V. K., Jansiewica, E. M., Goldberg, M., & Denckla, M. B. (2006). Developmental dyspraxia is not limited to imitation in children with autism spectrum disorder. *Journal of the International Neuropsychological Society*, *12*, 314–326. doi:10.1017/S1355617706060437

Mulligan, S. (1996). An analysis of score patterns of children with attention disorders on the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy*, *50*(8), 647–654.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy*, *52*, 819–828.

Nelson, A. B., & Kreitzer, A. C. (2014). Reassessing models of basal ganglia function and dysfunction. *Annual Review of Neuroscience*, *37*, 117.

O'Riordan, M., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders*, *36*(5), 665–675. doi:10.1007/s10803-006-0106-1

Ozonoff, S., Young, G. S., Goldring, S., Greiss-Hess, L., Herrera, A. M., Steele, J., . . . Rogers, S. J. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders*, *38*(4), 644–656. doi:10.1007/s10803-007-0430-0

Parham, L., Ecker, C., Miller Kuhaneck, H., Henry, D., & Glennon, T. (2007). *Sensory Processing Measure (SPM) manual*. Los Angeles, CA: Western Psychological Services.

Pearsall-Jones, J. G., Piek, J. P., & Rigoli, D. (2011). Motor disorder and anxious and depressive symptomatology: A monozygotic co-twin control approach. *Research in Developmental Disabilities*, *32*(1), 1245–1252.

Peterka, R. J., Statler, K. D., Wrisley, D. M., & Horak, F. B. (2011). Postural compensation for unilateral vestibular loss. *Frontiers in Neurology*, *2*, 57. doi:10.3389/fneur.2011.00057

Piek, J. P., Bradbury, G. S., Elsley, S. C., & Tate, L. (2008). Motor coordination and social–emotional behaviour in preschool-aged children. *International Journal of Disability, Development and Education*, *55*(2), 143–151.

Piek, J. P., & Coleman-Carman, R. (1995). Kinesthetic sensitivity and motor performance in children with developmental coordination disorder. *Developmental Medicine and Child Neurology*, *37*, 976–984.

Pitcher, T. M., Piek, J. P., & Hay, D. A. (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine & Child Neurology*, *45*(8), 525–535.

Pless, M., & Carlsson, M. (2000). Effects of motor skill intervention on developmental coordination disorder: A meta-analysis. *Adapted Physical Activity Quarterly*, *17*, 381–401.

Plotnik, M., Shema, S., Dorfman, M., Gazit, E., Brozgol, M., Giladi, N., & Hausdorff, J. M. (2014). A motor learning-based intervention to ameliorate freezing of gait in subjects with Parkinson's disease. *Journal of Neurology*, *261*(7), 1329–1339.

Polatajko, H. J., & Cantin, N. (2010). Exploring the effectiveness of occupational therapy interventions, other than the sensory integration approach, with children and adolescents experiencing difficulty processing and integrating sensory information. *American Journal of Occupational Therapy*, *64*(3), 415–429.

Poulsen, A. A., Ziviani, J. M., Cuskelly, M., & Smith, R. (2007). Boys with developmental coordination disorder: Loneliness and team sports participation. *American Journal of Occupational Therapy*, *61*, 451–462.

Pratt, M. L., & Hill, E. L. (2011). Anxiety profiles in children with and without developmental coordination disorder. *Research in Developmental Disabilities*, *32*(1), 1253–1259.

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2012). *Neuroscience* (5th ed.). Sunderland, MA: Sinauer Associates, Inc.

Reed, E. (1988). From the motor theory of perception to the perceptual control of action. In E. S. Reed (Ed.), *James J. Gibson and the psychology of perception* (pp. 67–88). New Haven, CT: Yale University.

Rine, R. M. (2009). Growing evidence for balance and vestibular problems in children. *Audiological Medicine*, *7*(3), 138–142.

Rine, R. M., & Wiener-Vacher, S. (2013). Evaluation and treatment of vestibular dysfunction in children. *NeuroRehabilitation*, *32*(3), 507–518.

Roebers, C. M., & Kauer, M. (2009). Motor and cognitive control in a normative sample of 7-year-olds. *Developmental Science*, *12*(1), 175–181. doi:10.1111/j.1467-7687.2008.00755.x

Roley, S. S., Mailloux, Z., Parham, D., Schaaf, R., Lane, C. J., & Cermak, S. (2015). Sensory Integration and Praxis patterns in children with autism. *American Journal of Occupational Therapy*, *69*. doi:10.5014/ajot.2015.012476

Rosblad, B. (2002). Visual perception in children with developmental coordination disorder. In S. Cermak & D. Larkin (Eds.), *Developmental motor coordination disorder* (pp. 104–116). New York, NY: Delmar Thomson.

Rose, D. J., & Christina, R. W. (2006). *A multilevel approach to the study of motor control and learning* (2nd ed.). San Francisco, CA: Pearson/Benjamin Cummings.

Roy, E. A., Black, S. E., Stamenova, V., Hebert, D., & Gonzalez, D. (2014). Limb apraxia: Types, neural correlates, and implications for clinical assessment and function in daily living. In T. A. Schweizer & R. L. Macdonald (Eds.), *The behavioral consequences of stroke* (pp. 51–69). New York, NY: Springer.

Rutherford, M. D., & Rogers, S. J. (2003). Cognitive underpinnings of pretend play in autism. *Journal of Autism and Developmental Disorders*, *33*(3), 289–302.

Schaaf, R. C., Schoen, S. A., Smith Roley, S., Lane, S. J., Koomar, J., & May-Benson, T. A. (2010). A frame of reference for sensory integration. In P. Kramer & J. Hinojosa (Eds.), *Frame of reference for pediatric occupational therapy* (3rd ed., pp. 99–186). Philadelphia, PA: Lippincott Williams & Wilkins.

Schmahmann, J. D., Anderson, C. M., Newton, N., & Ellis, R. (2002). The function of the cerebellum in cognition, affect and consciousness: Empirical support for the embodied mind. *Consciousness & Emotion*, *2*(2), 273–309.

Schmidt, R., & Lee, T. (2013). *Motor learning and performance, 5E with web study guide: From principles to application*. Champaign, IL: Human Kinetics Pub Inc.

Serino, A., & Haggard, P. (2010). Touch and the body. *Neuroscience Biobehavioral Review*, *34*(2), 224–236. doi:10.1016/j.neubiorev.2009.04.004
Shaw, L., Levine, M. D., & Belfer, M. (1982). Developmental double jeopardy: A study of clumsiness and self esteem in children with learning problems. *Journal of Developmental and Behavioral Pediatrics*, *3*(4), 191–196.
Shumway-Cook, A., & Woollacott, M. (2011). *Motor control: Translating research into clinical practice* (4th ed.). Baltimore, MD: Williams & Wilkins.
Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences*, *7*(8), 343–348.
Smits-Engelsman, B. C., Blank, R., van der Kaay, A. C., Mosterd-van der Meijs, R., Vlugt-van den Brand, E., Polatajko, H. J., & Wilson, P.H. (2013). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: A combined systematic review and meta-analysis. *Developmental Medicine and Child Neurology*, *55*(3), 229–237. doi:10.1111/dmcn.12008
Smits-Engelsman, B. C., & Hill, E. L. (2012). The relationship between motor coordination and intelligence across the IQ range. *Pediatrics*, *130*(4), e950–e956. doi:10.1542/peds.2011-3712
Sober, S. J., & Sabes, P. N. (2005). Flexible strategies for Sensory Integration during motor planning. *Nature Neuroscience*, *8*(4), 490–497.
Soderstrom, N., & Bjork, R. (2013). Learning versus performance. *Oxford Bibliographies in Psychology*. doi:10.1093/obo/978-199828340-0081
Stanfield, A. C., McIntosh, A. M., Spencer, M. D., Philip, R., Gaur, S., & Lawrie, S. M. (2008). Towards a neuroanatomy of autism: A systematic review and meta-analysis of structural magnetic resonance imaging studies. *European Psychiatry*, *23*(4), 289–299.
Steinman, K. J., Mostofsky, S. H., & Denckla, M. B. (2010). Toward a narrower, more pragmatic view of developmental dyspraxia. *Journal of Child Neurology*, *25*(1), 71–81. doi:10.1177/0883073809342591
Stephenson, E. A., & Chesson, R. A. (2008). ‘Always the guiding hand’: Parents’ accounts of the long-term implications of developmental co-ordination disorder for their children and families. *Child Care Health Development*, *34*(3), 335–343. doi:10.1111/j.1365-2214.2007.00805.x
Sugden, D., Kirby, A., & Dunford, C. (2008). Issues surrounding children with developmental coordination disorder. *International Journal of Disability, Development and Education*, *55*(2), 173–187.
Sugden, D., & Keogh, J. (1990). *Problems in movement skill development*. Columbia, South Carolina: University of South Carolina Press.
Summers, J., Larkin, D., & Dewey, D. (2008). Activities of daily living in children with developmental coordination disorder: Dressing, personal hygiene, and eating skills. *Human Movement Science*, *27*(2), 215–229.
Tracy, J., Flanders, A., Madi, S., Laskas, J., Stoddard, E., Pyrros, A., . . . DelVecchio, N. (2003). Regional brain activation associated with different performance patterns during learning of a complex motor skill. *Cerebral Cortex*, *13*(9), 904–910.
Ullsperger, M., Danielmeier, C., & Jocham, G. (2014). Neurophysiology of performance monitoring and adaptive behavior. *Physiological Reviews*, *94*(1), 35–79.
Vaivre-Douret, L. (2014). Developmental coordination disorders: State of art. *Neurophysiologie Clinique/Clinical Neurophysiology*, *44*(1), 13–23.
Verhoeven, J. S., de Cock, P., Lagae, L., & Sunaert, S. (2010). Neuroimaging of autism. *Neuroradiology*, *52*(1), 3–14. doi:10.1007/s00234-009-0583-y
Viholainen, H., Ahonen, T., Cantell, M., Lyytinen, P., & Lyytinen, H. (2002). Development of early motor skills and language in children at risk for familial dyslexia. *Developmental Medicine and Child Neurology*, *44*, 761–769.
Warren, J. E., Wise, R. J., & Warren, J. D. (2005). Sounds do-able: Auditory–motor transformations and the posterior temporal plane. *Trends in Neurosciences*, *28*(12), 636–643.
Wassenberg, R., Feron, F. J., Kessels, A. G., Hendriksen, J. G., Kalff, A. C., Kroes, M., . . . Vles, J. S. (2005). Relation between cognitive and motor performance in 5- to 6-year-old children: Results from a large-scale cross-sectional study. *Child Development*, *76*(5), 1092–1103. doi:10.1111/j.1467-8624.2005.00899.x
Williams, D. L., Goldstein, G., & Minshew, N. J. (2006). Neuropsychologic functioning in children with autism: Further evidence for disordered complex information-processing. *Child Neuropsychology*, *12*(4-5), 279–298.
Wilson, B., Pollock, N., Kaplan, B., & Law, M. (2000). *Clinical observation of motor and postural skills: Administration and scoring manual* (2nd ed.). Framingham, MA: Therapro, Inc.
World Health Organization. (2010). *International statistical classification of diseases and health related problems*. Geneva, Switzerland: World Health Organization.
Zhu, J. L., Olsen, J., & Olesen, A. W. (2012). Risk for developmental coordination disorder correlates with gestational age at birth. *Paediatric and Perinatal Epidemiology*, *26*(6), 572–577.
Zwicker, J. G., Harris, S. R., & Klassen, A. F. (2013). Quality of life domains affected in children with developmental coordination disorder: A systematic review. *Child: Care, Health and Development*, *39*(1), 562.
Zwicker, J. G., Missiuna, C., Harris, S. R., & Boyd, L. A. (2010). Brain activation of children with developmental coordination disorder is different

than peers. *Pediatrics*, *126*(3), e678–e686. doi:10.1542/peds.2010-0059

Zwicker, J. G., Missiuna, C., Harris, S. R., & Boyd, L. A. (2012). Developmental coordination disorder: A review and update. *European Journal of Paediatric Neurology*, *16*, 573–581. doi:10.1016/j.ejpn.2012.05.005

Zwicker, J. G., Yoon, S. W., MacKay, M., Petrie-Thomas, J., Rogers, M., & Synnes, A. R. (2013). Perinatal and neonatal predictors of developmental coordination disorder in very low birthweight children. *Archives of Disease in Childhood*, *98*(2), 118–122.

CHAPTER 6

Sensory Modulation Functions and Disorders

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Only recently has the professional literature begun to describe sensory modulation dysfunction. Practicing clinicians desperately need rigorous study designs to provide empirical data related to this disorder. Only through implementing and reporting well-controlled, rigorous studies will investigators be able to answer questions such as, Is SMD a valid syndrome? Does occupational therapy help ameliorate the condition? What are the underlying mechanisms in the disorder?

—Miller, L. J., & Summers, C., 2001

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe sensory modulation function on a cellular and behavioral level.
- ✔ Relate historical constructs relative to sensory modulation dysfunction (SMD) to current conceptualizations.
- ✔ Relate behaviors associated with sensory modulation function and dysfunction to central nervous system (CNS) structures.
- ✔ Reflect on our current understanding of sensory modulation disorders.
- ✔ Describe available research examining sensory modulation disorders in children with and without comorbid diagnoses.

Purpose and Scope

Sensory processing . . . sensory registration . . . sensory integration . . . sensory modulation . . . sensory reactivity. . . . We use these terms both academically and clinically, yet from one clinic to another, from one academic institution to another, and even from one profession to another, the intended meaning of the terms may differ. Adding complexity, some of these terms suggest neural functions, some suggest the outward behavioral manifestation of what we assume to be neural functions, and some have been used interchangeably to imply either. For consistency, we have provided some definitions in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited). Consistent with these definitions, and the model depicted in Figure 1-6, we have endeavored a move toward consistency in this text, as was noted in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited).

In considering sensory modulation, we begin with a child, depicting one of the sensory modulation concerns clinicians have identified. This is followed by reiterating some definitions specific to this chapter, and then we move to examine modulation, first on a cellular level and then on systems and behavioral levels. Next, we explain the concept of sensory modulation dysfunction (SMD). Hypothesized links to the limbic system and a proposed relationship between modulation dysfunction and stress leads to a discussion of these issues as well. We look at SMD as a whole and then discuss specific types of modulation dysfunction within the tactile and vestibular-proprioceptive systems. We close with a brief look at sensory over-reactivity within other sensory systems.

CASE STUDY ▪ MICHAEL

Observed in the classroom, 10-year-old Michael appears not to be paying attention to the lesson at hand. He is very quiet and does not volunteer information that adds to the discussion under way. His teacher questions if he is processing the information at all. Michael does not engage with other children to any great extent, and he plays alone on the playground. Currently Michael is classified by the school system as "other health impaired." He has an individualized education program (IEP) and receives both educational assistance and occupational therapy. His IEP states that one of his needs is for the opportunity to get more movement and deep pressure input during the day in order to improve his ability to attend and process. Incorporating this input throughout the school day is becoming difficult because, in fifth grade, Michael's teachers are not comfortable with these accommodations in the classroom, and Michael is less comfortable with anything that makes him appear different from his classmates.

Recently a Sensory Profile™ 2 (SP2) (Dunn, 2014) was completed. It can be scored as sensory system scores and summed into quadrant scores. Scores in each sensory section are as follows:

- Tactile: 29, much more than others
- Auditory: 6, less than others
- Visual: 7, less than others
- Movement: 27, much more than others
- Proprioception: 5, similar to the majority of others

Behavioral section scores included:

- Conduct: 25, more than others
- Social emotional: 30, similar to the majority of others
- Attentional: 27, more than others

Quadrant scores indicated that Michael shows indicators in all quadrants. He shows over-responsivity to touch, which is largely responsible for the high score in the *avoider* quadrant (score of 52; more than others). Scores in response to his visual and auditory environment suggest some reduced responsivity, as do his responses to movement, reflected on the SP2 as poor sensory registration (score of 66; much more than others). Michael also seeks additional movement and deep touch input throughout his daily routines (score of 65; much more than others). Overall, it was determined that Michael has a deficit in sensory modulation, most clearly seen with diminished responsivity in some sensory systems; over-responsivity to touch; and sensory-seeking behavior within the vestibular and proprioceptive systems. These modulation difficulties are linked to both behavioral and emotional regulation problems, presenting as difficulty paying attention to tasks at hand, a tendency not to attend within an active environment, and a high level of emotional reactivity to sensory input. These difficulties are very consistent with those over which his mother, Mrs. S., has expressed concern and are of a nature to impair his ability to work within the classroom.

Sensory Modulation

Modulation of sensory input is critical to our ability to engage in daily occupations (Bar-Shalita, Vatine, & Parush, 2008). Filtering of sensations and attending to those that are relevant, maintaining an optimal level of arousal, and maintaining attention to task all require modulation (S. J. Lane, Lynn, & Reynolds, 2010). When modulation is inadequate, attention may be diverted continually to ongoing changes in the sensory environment. We become distracted and attend to all input; this alters our arousal state such that it is no longer optimal.

Modulation as a Physiological Process at the Cellular Level

According to the Cambridge Dictionaries online, to modulate means "to change something, such as an action or a process, to make it more suitable for its situation" (http://dictionary.cambridge.org/dictionary/british/modulate). Within the central nervous system (CNS), modulation is reflected in neuronal activity that is enhanced or dampened in response to various sources of input to meet current demands. At the cellular level, both sensory receptor cells in the periphery and neuronal cells within the CNS may become more or less responsive to input. An incoming sensory signal is received by a receptor specific to that signal. The receptor can be highly responsive to input or, through time, can adapt to continued input and cease to respond. After reception, a stimulus must be transduced into an electrical signal to be carried to the CNS. As noted in Chapter 4 (Structure and Function of the Sensory Systems), transduction involves changing the energy of the initial signal (e.g., sound waves for the auditory system or movement for the vestibular system) into electrical and chemical energy. When these changes are of sufficient strength, an electrical signal, known as an **action potential,** is generated and carried to the cell body of the first order neuron. From this initial point of entry, the electrical signal can be propagated to interact with the cell bodies, other axons, or dendrites of other neurons within the CNS.

At the synapse, or point of interaction between neurons, the electrical signal changes to a chemical signal and activates neurotransmission. Neurotransmitters are released and travel across the synaptic cleft to interact with specific receptors on the postsynaptic membrane. Figure 6-1 depicts this process schematically. Neurotransmitters can be either excitatory or inhibitory. Some have been shown to always be either excitatory or inhibitory; for instance, glutamate is an excitatory neurotransmitter found widely throughout the brain. Interestingly, glutamate is the precursor, or building block, for gamma-aminobutyric acid (GABA), the chief inhibitory neurotransmitter in the CNS. Neurotransmitters such as dopamine or serotonin are either excitatory or inhibitory, depending on the characteristics of the receptor with which they interact. As an example, there are at least five types of dopamine receptors in the brain, which can be broadly grouped into D-1 like and D-2 like families. At some D-1 like sites, dopamine opens sodium channels, leading to excitation and a neural signal being sent on; at other D-1 like sites, dopamine opens potassium channels instead, inhibiting signal propagation. Action at D-2 like receptors is almost always inhibitory (Purves et al., 2011). Receptors for serotonin are even more complex, and are beyond the scope of this discussion.

For simplicity in understanding balancing of excitation and inhibition, we will consider hypothetical transmitters interacting with one type of receptor, resulting in an action that is always excitatory or inhibitory. Because more than one axon makes contact with the same postsynaptic neuron, potentially there will be competing inputs, some excitatory and others inhibitory and some strong and others weak. Thus, no single input is likely to excite the postsynaptic membrane sufficiently to send the message on further. What determines if the signal will be further propagated is, to some extent, the algebraic sum of all inputs. Factors, such as the strength and frequency of input and the location of the synapse relative to the cell body, influence this sum as well. Thus, modulation at the cellular level comes from activation of specific inputs to a cell; increasing excitatory inputs results in the postsynaptic cell firing and sending the information forward. Increased inhibitory inputs will "block" further transmission of the impulse. In Figure 6-2, this is diagrammed simplistically. Here there is a preponderance of inhibitory inputs; thus, the target cell (shaded) will be *inhibited* from firing.

As an example, consider a very simplified version of the nervous system, such as that depicted in Figure 6-2. Neuron A carries sensation from a sharp, quick pinch and releases an excitatory neurotransmitter onto the postsynaptic membrane. Intense or repeated signals activate the postsynaptic cell to further transmission of the signal, say to the thalamus, where the sensation of pain could be identified. However, if the pinched spot is pressed on or rubbed, another set of incoming neurons is activated (e.g., neuron B), carrying deep pressure. Assume this new input makes a connection with the same central neuron but leads to the release of an inhibitory transmitter. If the signal ratio were one to one (i.e., one pinch activation for one deep pressure rub activation) with similar strengths and contact points, then one signal would cancel the other and there would be no propagation of input and no sensation of pain. However, if the pinch is intense or prolonged, an increase in the frequency or intensity of transmission regarding the deep pressure neuron might be needed to cancel the sensation of pain completely. Even without a complete cancellation, transmission of this painful input is *modulated,* or not as intense as it would have

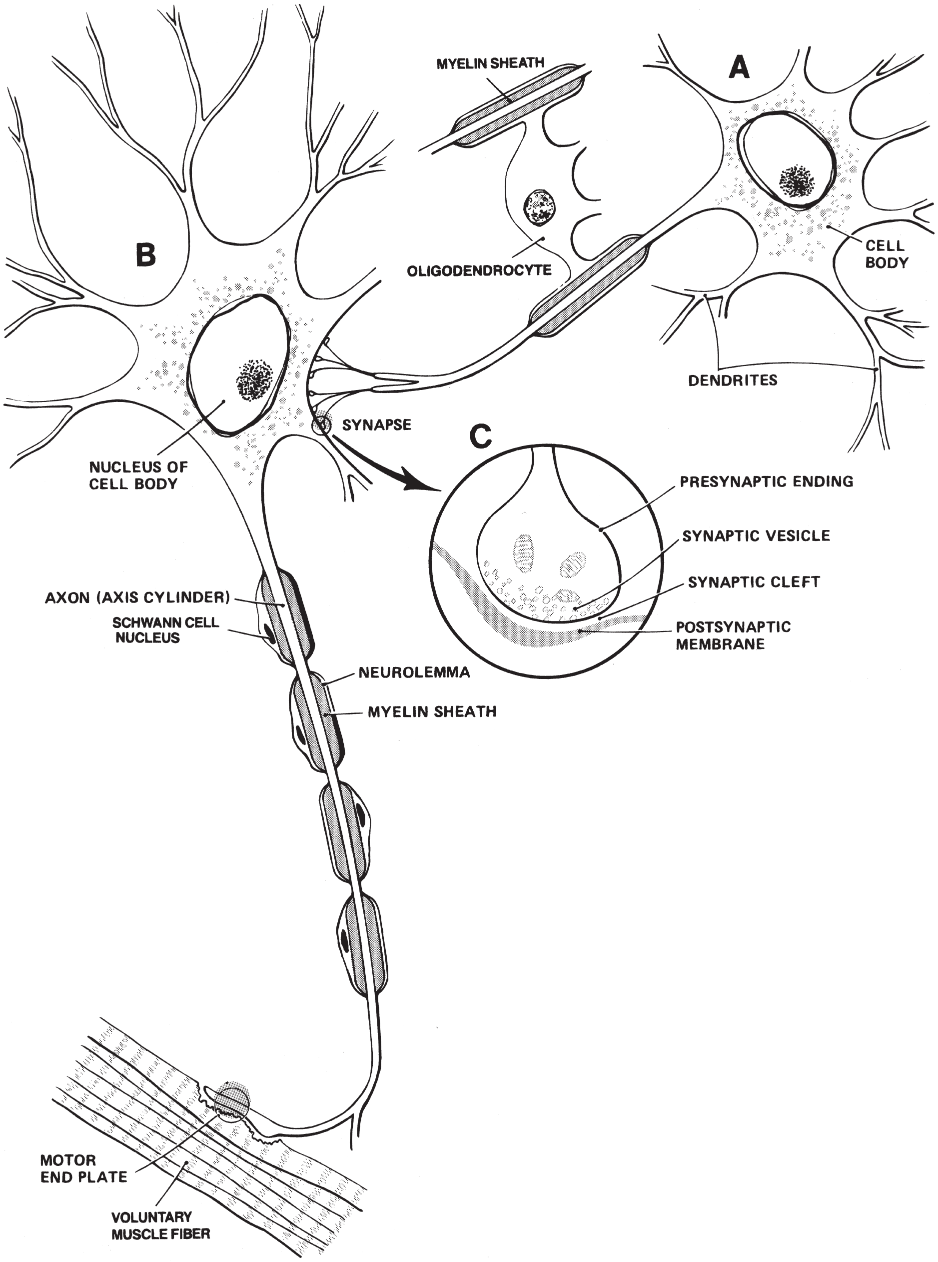

FIGURE 6-1 Synapse and synaptic transmission. Neuron A is shown synapsing with neuron B. This synapse is shown in greater detail in C, where the presynaptic vesicle, synaptic cleft, and postsynaptic membrane are indicated. Neuron A is also shown, surrounded by projections from an oligodendrocyte (a glial cell; see Chapter 2, Sensory Integration in Everyday Life, for more information on neurons and glia). *Adapted from Gilman and Newman, 1992, and reprinted with permission from Gilman, S., & Newman, S. W. (1992).* Essentials of clinical neuroanatomy and neurophysiology *(9th ed., p. 4). Philadelphia, PA: F.A. Davis.*

been without the deep pressure. In Figure 6-2, neuron C may come from higher level centers in the brainstem or thalamus. The combination of inhibition from the periphery and the CNS in this case cancel further transmission of pain; it does not reach the level of the CNS required for sensory detection.

Clearly, single cell input to the CNS offers a greatly oversimplified perspective on modulation, but it does provide a useful place to

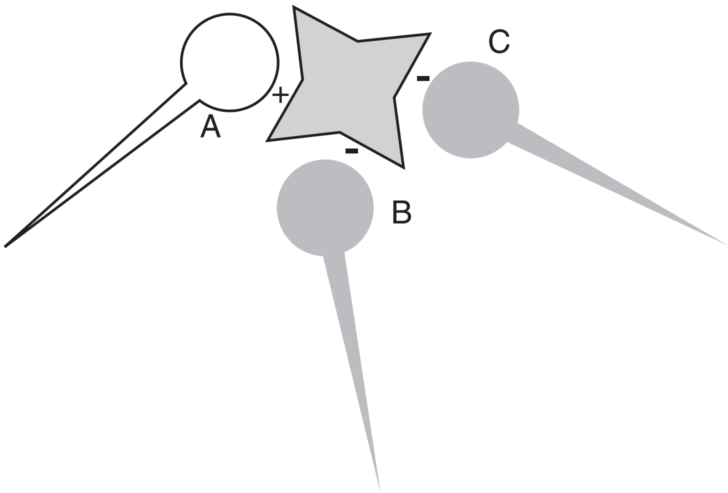

FIGURE 6-2 Balancing excitatory and inhibitory inputs. This neuron (shaded) receives both excitatory (neuron A, white) and inhibitory (neurons B and C, gray) inputs. In this figure the sum of inputs would favor inhibition of further neurotransmission.

start. The interconnectivity of the CNS is very complex, and many factors influence modulation. Still, the bottom line at the cellular level is that some inputs are excitatory and some are inhibitory; some are strong and some are weak; some are fast and some are slow. The algebraic sum of these factors, along with some essential characteristics of the synapse, determines what the CNS experiences from the periphery and what it does with this information. If we make a cautionary link to the next level, these same concepts can be used to develop a parallel understanding of modulation from a sensory system and behavioral level.

Modulation at the Level of Systems and Behavior

Separating neurophysiological systems from behavior is difficult because we only see systems at work when we observe behavior. Thus, we will look at behavioral and neurophysiological modulation together. However, you are encouraged to distinguish between descriptions of behavior and those of neurophysiological processes.

If we view the cellular model more realistically, it becomes clear that many neurons are receiving inputs from multiple sources simultaneously. CNS structures process incoming input and generate responses that reflect acceptably modulated behavior. Ayres (1979) defined *modulation* as "the process of increasing or reducing activity to keep the activity in harmony with all functions of the nervous system" (p. 182). Modulation at the cellular level allows a person to respond at the behavioral level to relevant input, not to respond to what is irrelevant, and to do so in a manner that promotes adaptive environmental interaction. The link between modulation and behavior has been reinforced in research findings, indicating that adequate modulation facilitates engagement in satisfying and meaningful occupations (Bar-Shalita et al., 2008; Reynolds, Bendixen, Lawrence, & Lane, 2011; Reynolds & Lane, 2008) and that difficulties with modulation can negatively impact quality of life (QoL; Bar-Shalita, Deutsch, Honigman, & Weissman-Fogel, 2015).

The act of balancing excitatory and inhibitory inputs in the CNS and responding only to those that are relevant (i.e., our work to "maintain harmony") goes on subconsciously. For most, the ability to generate a modulated behavioral response is present, albeit unrefined, at birth. For instance, a fatigued infant begins to cry, finds a thumb, and begins to suck. The clinician may infer that by using somatosensory input (deep pressure to the mouth), the infant has modulated his or her emotional response and has found a way to behave in a socially acceptable manner—to self-calm. Deep pressure and touch within the mouth, transmitted through the somatosensory

HERE'S THE EVIDENCE

Bar-Shalita and Cermak (2016) wished to examine the relationship between what they termed *Atypical Sensory Modulation* and psychological distress (e.g., anxiety) in the general population. They defined ASM as an aspect of poor sensory processing that negatively impacted the ability to grade responses to single or multisensory inputs, and indicated that ASM might be reflected in over-responsivity, under-responsivity, or sensory seeking (SS). Participants in their study were adults with no identified disorders or family history of psychopathology. Participants completed the Sensory Responsiveness Questionnaire-Intensity Scale, which the authors had developed in an earlier study. On completion of the SRQ-IS, the group of participants was subdivided into those with ASM (greater than or equal to 2 SD from the SRQ-IS mean; 12.75% of the total group, $n = 26$) and a comparison group of individuals scoring within the cutoff range on the SRQ-IS (mean ± 2 SD; $n = 178$). All participants completed the Brief Symptom Inventory (BSI), a tool that identifies psychological symptoms through a series of psychological dimensions. The Short Form-36 Health Survey was also completed to provide insight into perceived QoL in areas of physical health. Investigators found that adults with ASM had more psychological symptoms than the comparison group. Although scores were within a typical range for both groups, investigators suggest that the overall increased symptoms might reflect a risk factor for the future. QoL related to physical health was substantially lower for adults in the ASM group, leading investigators to suggest that QoL for otherwise typical adults was "vulnerable." In a final analysis, these investigators found that together QoL and ASM predicted psychological distress. Investigators indicate that psychological distress is itself a risk factor for the development of other mental health conditions, and as such ASM, or SMD, might also be considered a risk factor for later development of mental ill-health. Early identification and intervention may be the best practice for these individuals.

Bar-Shalita, T., & Cermak, S. A. (2016). Atypical sensory modulation and psychological distress in the general population. *American Journal of Occupational Therapy, 70,* 1–9.

system, provided sufficient inhibitory input to the cells in the CNS to modulate arousal.

As the nervous system matures, develops more connections, and grows myelin, the ability to modulate one sensory system's activity, via input to another system, also refines. This internal growth and development is supplemented by environmental inputs, instilling an understanding of appropriate environmental interactions and how such an interaction is generated (Purves et al., 2011).

The art of modulating behavior through the use of sensation becomes personalized. What works for one does not necessarily work for another. One mother learns early on that close chest-to-chest contact is the only means of quieting her infant. Rocking, bouncing, and patting all seem to increase the infant's agitation rather than help her settle down. In periods of quiet alertness, this baby enjoys these latter inputs, but when she is upset, they only make it worse. Another mother finds that her infant needs to be rocked or jiggled; cuddling alone is insufficient to help this second baby calm down. Different sensations work to help these infants modulate their arousal and anxiety. This was also true for Michael. He found tactile input discomforting rather than comforting; his ability to interpret and modulate tactile input was compromised; in contrast, he found movement and proprioception settling.

To further illustrate this concept, consider toddlers in a playgroup using a slide. We see one child, Beth, who is very excited about this opportunity. She has been running in circles from the bottom of the slide to the stairs for several minutes, and this seems to be a great way to use up her energy. However, she gets more and more excited each time she gets to slide down the slide. She runs back to the stairs for more but seems to become less coordinated with each turn, finally slipping on the stairs on the way up and screaming in frustration. She requires the intervention of a child-care worker before she can calm down and move on to another activity.

Sam, on the other hand, has been sitting and watching, seemingly not looking forward to a turn on the slide, or any other activity for that matter. The care provider guides him to the slide, assists him in the climb, and offers support the first time down. He smiles, walks back to the steps, and looks for assistance to do it again. The next time, Sam climbs alone, checks in with the care provider, and slides alone; another smile emerges. After four or five slides, he is finished and becomes invested in some blocks and cars in another part of the room.

In this instance, the same activity, sliding, increased arousal in both children, but the input had a very different modulatory impact on their behavior. For Beth, the slide was fun but was disorganizing in the long run. Based on her behavior, we infer that the ongoing vestibular and proprioceptive sensations raised her level of arousal beyond the point of adaptive environmental interaction. She needed to pull back and receive another form of input (i.e., comforting from the caregiver) before she was ready for another activity. For Sam, the sliding was activating. His apparently low level of arousal and sensory detection were increased through this activity, and, for Sam, this was critical for improving his ability to generate subsequent environmental interactions.

HERE'S THE POINT

- Modulation of sensation needs to be considered at both a cellular and behavioral level.
- At the cellular level, modulation involves the actions of neurotransmitters on neuron receptors. These actions may inhibit a sensory signal from being sent forward, excite the receptor to support transmission of the signal, or serve to moderate the signal.
- We see the behavioral outcome of cellular modulation reflected in activity; adequate cellular modulation supports our ability to respond to sensation behaviorally in a manner that promotes adaptive environmental interaction and facilitates engagement in meaningful occupations.

Sensory Modulation Dysfunction

Modulate: "To change or adjust (something) so that it exists in a balanced or proper amount" (Merriam Webster Online, 2015). Disorders of sensory modulation then reflect difficulty with this balance process; we see either too little adjustment or too much adjustment. Importantly from a sensory integrative perspective, ". . . it is a mismatch between the external contextual demands of a person's world (e.g. culture, environment, tasks, and relationships) and a person's internal characteristics" (Hanft, Miller, & Lane, 2000, p. 1). Sensory modulation disorders have been described slightly differently by recent investigators. In the next section we examine the evolution of these definitions.

A Brief Historical Overview

Ayres described tactile defensiveness as early as 1964, linking it with hyperactivity and inattention (Ayres, 1964). In this theoretical manuscript, Ayres described the features of tactile defensiveness as an imbalance between protective and discriminative systems, resulting in discomfort with touch and a desire to escape from it. She further suggested that tactile defensiveness might be seen in combination with defensiveness in other systems (Ayres, 1972). This was extended by Knickerbocker (1980), who introduced the term **sensory defensiveness** to describe a disorganized response to sensory input across more than one sensory system. Specifically, she implicated olfactory (O), tactile (T), and auditory (A) systems, terming this the "OTA triad." Children with such sensory defensiveness were characterized as overly active, hyper-verbal, distractible, and disorganized. Knickerbocker (1980) also described sensory dormancy, characterized by disorganized and immature behavior, resulting from excessive inhibition of incoming sensory input and a lack of sensory arousal. Dormancy could be observed in the olfactory, tactile, and auditory systems. Knickerbocker described a child experiencing sensory dormancy as being quiet and compliant. The constructs of sensory defensiveness and dormancy were further considered by several other theorists and investigators (Cermak, 1988; Lai, Parham, & Johnson-Ecker, 1999; Royeen, 1989; Royeen & Lane, 1991). And, although these sensory responses appear to form a continuum, there was not sufficient evidence found to support this relationship. Although clinicians address subcategories of disorders, including tactile defensiveness; gravitational insecurity; and defensiveness to smell and taste, sound, and light; the work of McIntosh, Miller, Shyu, & Hagerman (1999) suggested a more general underlying SMD in which poor modulation in the different systems appears to be related.

Other authors (Dunn, 1997, 2014; Parham & Mailloux, 1996; Wilbarger & Wilbarger, 1991) indicated that sensory modulation was multidimensional, rather than representing a basic continuum; that children may not routinely over- or under-respond to sensation but instead may show sensory over-responsiveness to some sensations and under-responsiveness to others. And, there may be responsiveness changes across the span of a day, and in different contexts. Disorders of modulation then may reflect the child's difficulty finding the middle ground, across different contexts, where the appropriate level of modulation exists to allow him or her to interact adaptively with the environment. The resultant behaviors reflect a cascade of events within the CNS that affect attention, arousal, emotional stability, and cognitive processing.

Miller, Anzalone, Lane, Cermak, and Osten (2007) proposed a sensory processing nosology in which sensory modulation was one component of overall sensory integrative and processing deficits. This model paralleled that proposed and discussed by Ayres and others, indicating that disorders of modulation reflected difficulty processing the degree, nature, or intensity of the sensory input, resulting in behaviors that failed to match environmental expectations and demands in a manner that was appropriate developmentally. The categories of over- and under-responsivity were described, indicating that sensory over-responsivity (SOR) might be reflected in behaviors ranging from negativity, aggression, and impulsivity to withdrawal, to avoidance or passivity. SOR was also linked with sympathetic nervous system (SNS) activation, which itself is characterized by the fight, flight, and flee responses (Miller et al., 1999; Miller et al., 2007). Sensory under-responsivity (SUR) was identified as seeming unaware of a sensation of typical intensity and duration. Children evidencing SUR might appear to ignore input or fail to notice it. SS was also included, consistent with a model proposed by Dunn in 1997; it was defined as craving sensation of high intensity or long duration. Children engaging in SS create opportunities for sensation (e.g., drumming on every surface they pass as they walk down the hall). Importantly, SS as a modulation disorder was seen as an unusual need for intense, prolonged, or unusual input. Authors acknowledged that children with typical modulation might seek sensation. For instance, a young child who learns to climb onto and jump off the couch might repeat this pattern of movement several times, laughing with the intensity of his or her landing. He or she would, however, move on to something else. Miller and colleagues have continued to investigate aspects of sensory modulation subtyping. Using a newly developed tool, the Sensory Processing 3 Dimensions, they have substantiated these same three subtypes (SOR, SUR, and sensory craving) (Schoen, Miller, & Sullivan, 2014, 2016). More information is available in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research).

Dunn (1997, 1999) proposed and recently updated (Dunn, 2014) a conceptual model that links the neurological threshold to behavioral responsiveness (Fig. 6-3). She described two continua, one related to neurological threshold and another related to self-regulation. Dunn also defined four sensory processing patterns that reflect the intersection and interaction of the continua: poor registration, sensation seeking, sensation avoiding, and sensory sensitivity. Registration is defined as a sensory modulation deficit characterized by high neurological thresholds and passive behavioral self-regulation; children with this pattern of processing respond less to available sensation, missing aspects of sensory input.

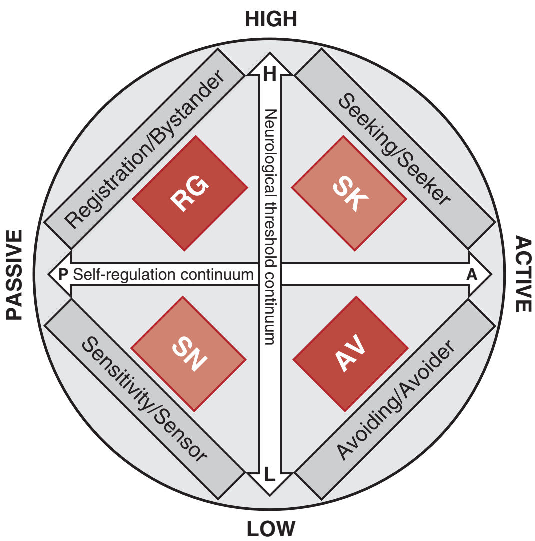

FIGURE 6-3 Dunn's conceptual model that links the neurological threshold to behavioral responsiveness.

Dunn termed those with this pattern as *bystanders*. Sam's environmental interactions reflect a degree of under-responsiveness to sensations available in the environment and through activity; he needs a lot of input to get going. Using Dunn's terminology, he has a higher than usual neurological threshold and relies on passive self-regulation. Coupling high neurological threshold with active self-regulation leads to seeking: Children who are driven to obtain sensation in greater intensity, frequency, or duration than that routinely available. Michael would be identified with this pattern of sensory modulation; he needs intense vestibular and proprioceptive sensations to allow for appropriate environmental interactions. The other two patterns within Dunn's framework reflect low neurological thresholds. Pairing a low threshold with passive self-regulation results in sensitivity, whereas low threshold with active self-regulation results in avoiding (Dunn, 2014).

Relatively recently, researchers have begun to examine links among sensory modulation disorders, physiological responses to sensation, and behavior. Although no cogent and unified model has emerged, some interesting characteristics have been identified. First, although sensory modulation deficits have been identified in children with diagnoses such as autism spectrum disorder (ASD) and attention deficit-hyperactivity disorder (ADHD) (Cheung & Siu, 2009; Dunn & Bennett, 2002; Kern et al., 2007; Kientz & Dunn, 1997; Wiggins, Robins, Bakeman, & Adamson, 2009), children with sensory modulation deficits and no identified comorbidities also have been characterized (Ben-Sasson, Soto, Heberle, Carter, & Briggs-Gowan, 2013; Reynolds, Lane, & Gennings, 2009). Electrophysiological findings suggest that children with SOR show SNS over-reactivity to sensation (Mangeot et al., 2001; Schoen, Miller, Brett-Green, & Nielsen, 2009). In addition, elevated anxiety has been linked with SOR (S. J. Lane, Reynolds, & Thacker, 2010).

Proposed Central Nervous System Links to Sensory Modulation Dysfunction

Recent examinations of sensory modulation disorder have moved the field forward in understanding neurological correlates of this concern. Most research has focused on sensory over-responsiveness and has examined links with the autonomic nervous system (ANS) and the stress response characterized by cortisol. A summary of this research can be found in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research) and Chapter 16 (Advances in Sensory Integration Research: Basic Science Research), respectively.

Theoretical and Hypothesized Links

The descriptors used in the previous section, related to emotional responses, attentional and arousal mechanisms, and sensory filtering, have contributed to theories and research relative to the mechanisms underlying modulation deficits in the CNS. These links are examined in the next section, and, when available, research findings relative to the relationships are discussed.

Sensory Modulation and the Limbic System

The group of structures we commonly refer to as the limbic system, and link to emotional regulation, may not be a unitary system (Bear, Connors, & Paradiso, 2015). As noted previously, clinicians and researchers had been describing behaviors related to limbic system function since the early 1960s, and there are clear links to sensation. Examining this relationship further, Royeen and Lane (1991) hypothesized that modulation dysfunction may have its roots in limbic regions and the hypothalamus. The source of this proposal was in the functions of these structures. Called the "mediator of all things emotional" (Restak, 1995, p. 18), Restak indicated that the limbic system includes three cortical areas (i.e., the cingulate gyrus, septum, and parahippocampal gyrus) and the gray matter areas of the hippocampus and amygdala (Fig. 6-4). Some scientists include the hypothalamus as a component of this group of structures (e.g., Siegel & Sapru, 2015; see Fig. 6-4); the hypothalamus has been linked with governing emotional expression through a reciprocal loop that connects the (neo) cortex and cingulate cortex, and the cingulate with the hippocampus, hypothalamus, and thalamus (Bear et al., 2015). Limbic regions receive input from all cerebral lobes and connecting fibers and project back to these areas; there are also extensive connections among limbic structures. Limbic regions are highly connected with the hypothalamus and related regions, and, as such, serve a function of modulating hypothalamic influences on somatic and ANS activity. Limbic structures

FIGURE 6-4 The limbic system is less an actual system than a group of structures. The structures include the amygdala, hippocampus, cingulate gyrus, septum, fornix, and mammillary body on each side of the brain. Sometimes the hypothalamus is also included in this system.

play a role in learning and memory; eating and drinking behaviors; aggression; sexual behavior; and, importantly, motivation and expression of emotion (Siegel & Sapru, 2015). The processing of sensation is a prominent function of some limbic structures. As such, the limbic system is a likely candidate for involvement in SMD.

Early on, Royeen and Lane (1991) had suggested that involvement of the limbic system: (a) provides an explanation for the emotional or social difficulties often accompanying tactile and sensory defensiveness, (b) accounts for the presence of defensiveness or dormancy across sensory systems, and (c) allows for extreme shifts or inconsistencies in responsivity (from defensiveness to dormancy) that may be observed in an individual either with regard to a single sensory system or across sensory systems (p. 122).

Even as we learn more about limbic structures, this continues to have theoretical logic and is beginning to engender some empirical support. For instance, the research of Miller and colleagues (1999), with children with fragile X syndrome, demonstrated differences in electrodermal response (EDR) to sensory challenge between children with fragile X syndrome and age- and gender-matched controls. The EDR is a reflection of SNS activation, mediated in part by the limbic-hypothalamic system (Edelberg, 1972; Fowles, 1986). Additional studies of individuals with fragile X syndrome have implicated the caudate, hippocampus, and thalamus (Gothelf et al., 2008; Lee et al., 2007; Reiss, Abrams, Greenlaw, Freund, & Denkla, 1995; Reiss, Lee, & Freund, 1994; A. Schneider, Hagerman, & Hessl, 2009). Using fMRI, Green and colleagues (2013) have similarly documented increased activity in regions of the limbic system (amygdala, hippocampus, and orbito-frontal cortex), as well as in the primary sensory cortex, during sensory challenge in individuals with ASD. Thus, increasingly we are establishing evidence indicating a link between the sensory modulation differences and limbic processing, although understanding these links requires ongoing investigation.

Because the limbic regions may be involved in modulation, a look at the functions associated with some of its structures is warranted. Studies of the limbic system have largely used animal models. As always, caution must be exercised in making the leap from animal studies to function within the human nervous system. Nonetheless, much can be learned by examining this work.

The **septal region** (see Fig. 6-4) has functions that parallel those of the hippocampus because it serves as a relay between the hippocampus and the hypothalamus. It receives input from the olfactory and limbic systems, and, along with projecting to the hypothalamus, fibers project to the epithalamus and other midbrain regions

(Waxman, 2010). The septum is thought to exert an inhibitory influence on the ANS and to play a role in the use of environmental stimulation; it permits the organism to attend to any stimulus in the environment, even those having low stimulus value (Isaacson, 1982). Thus, in a normal state, the septal region may play a role in our ability to attend to and interact successfully with the environment.

Lesions of the septal region have been shown to result in transient hyperemotionality in many rodents and humans (Isaacson, 1982). The increased emotionality can be reduced with handling and is less severe when an animal experiences the lesion during its youth. In addition, some animals with lesions appear to demonstrate exaggerated defensive reactions and show hyperresponsiveness to handling, light touch (air puffs), poking with a stick, temperature changes, light, and sounds (Donovick, 1968; Fried, 1972; Green & Schwartzbaum, 1968; Grossman, 1978; Olton & Gage, 1974). This hyperresponsivity is characterized by increases in motor activity. It is tempting to hypothesize then that this region is linked with SOR, and the "vigilant" behaviors (attending to all sensory input) often associated with SOR. Were Michael's difficulty attending, introduced earlier, linked more to appearing hypervigilant to all stimuli in his sensory environment, we might be concerned about function within this limbic region.

The **cingulate gyrus** (see Fig. 6-4) is a complex structure with numerous connections; it receives input from the hippocampus and has reciprocal connections with the anterior nucleus of the thalamus and portions of the temporal, parietal, and prefrontal association areas. It also sends input to the dorsal medial nucleus of the thalamus, a connection thought to be important in the affect associated with perception (Kingsley, 2000). As with other limbic structures, we are still learning about the various physiological functions associated with the cingulate gyrus; several functions have been linked with regions of the cingulate gyrus, including affect regulation, visceromotor control, response selection, visuospatial processing, and memory access. It may play a role in attaching emotional quality or meaning to sensory input, also in concert with the amygdala.

Bear and colleagues (2015) identify **affective aggression** as the emotional response of an animal in the presence of a threatening stimulus. In cats, for example, this might be the presence of another animal within its territory or posing a threat to a litter of kittens. The affective behaviors associated with such rage are strongly inhibited by output from the amygdala and facilitated by connections from the septal area and other limbic regions. This suggests a modulatory role in affective rage. Although likening affective aggression in animals to sensory modulation deficits is inappropriate, examining this mechanism gives us food for thought because it defines the limbic system as playing a role in the modulation of behavior resulting from environmental input that is perceived to be threatening. Referring back again to Michael, he does not demonstrate what would be considered "affective rage"; instead, he tends to withdraw from sensory stimuli to the point that his teacher questions whether he is adequately processing the information he receives.

Aside from its role in olfaction, current knowledge suggests a highly important role in fear conditioning and emotion recognition for the **amygdala** (see Fig. 6-4). Years ago, Pribram (1975) suggested that the amygdala made important contributions to an organism's ability to orient and detect sensory input; more recent work suggests that this structure is linked with recognition of emotional expression, especially fear, anger, sadness, and disgust (Siegel & Sapru, 2015). Amygdala activation has been linked with increased vigilance and attention, along with the expression of anxiety and fear. Recent work of Bruneau, Jacoby, and Saxe (2015) links the amygdala with the processing of other people's negative emotions (emotional empathy); the same is not true for other people's physical pain. Activation of the amygdala has long been associated with control of one's own emotional responses to distressing input. Reciprocal links between the amygdala and the frontal cortex may serve as a mechanism for attaching emotional significance to sensory input (Siegel & Sapru, 2015). The amygdala has numerous connections with the hippocampus. This relationship allows amygdalar activity to influence ANS functions. We might consider the possibility that some of the avoidance behaviors associated with SMD may be associated with the attachment of a negative emotional response to that sensory input within the amygdala.

The **hippocampus** (see Fig. 6-4), another limbic structure, also has been hypothesized to play a role in sensory modulation. Interestingly, this structure is less linked with emotional regulation and more linked with spatial mapping and memory, leading to the suggestion that this structure is not associated with emotional regulation (Bear et al., 2015). A large number of fibers link the hippocampus to the cortex. Functions associated with this structure include learning and memory, mediation of aggressive behavior (via connections in the septal region), and autonomic and endocrine functions (via connections with the hypothalamus) (Siegel & Sapru, 2015). This structure is considered highly important in memory consolidation, moving memories from short to long term. Siegel and Sapru suggested memory consolidation may be lost with hippocampal lesions because the processing of sensory input during learning is impaired. Hippocampal lesions result in a wide variety of behavioral alterations that seem to be related to an animal's genetic background and to the conditions under which a behavior was elicited. Here again, extreme caution must be taken in generalizing from animal studies to humans. However, hippocampal lesions result in animals' failing to persist in new tasks; they readily begin a goal-oriented task but will not stay with it to completion. There is also an increase in activity in some situations, especially during "open-field" testing. This increased movement is not associated with increased exploration; the animal seems to move about a great deal but fails to use the environmental information available from this increased movement effectively.

Finally, a role for the **hypothalamus** (see Fig. 6-4) in the process of sensory modulation has been suggested. This structure maintains an important and reciprocal relationship with the limbic structures and is often included in discussions of this system. It integrates information from the cortex (first processed through the amygdala and hippocampus) with input from the spinal cord and brainstem. In this respect, the hypothalamus is a control center for ANS mechanisms (Siegel & Sapru, 2015). Outputs from the amygdala project to the lateral hypothalamus to inhibit affective rage; as such, it is associated with the expression of this response. Dysfunction in the hypothalamus in humans, secondary to disease or injury, may be responsible for the onset of attack behavior and physically violent outbursts (Bear et al., 2015).

Thus, the purported functions of limbic and hypothalamic structures are consistent with modulation of sensory input. These structures play a role in attending to and processing environmental stimuli, attaching meaning and emotional significance to sensation, and the establishment of memory. Furthermore, dysfunction in regions of the limbic system elicits behaviors such as increased sensory responsivity, increased emotionality, and aggressive behaviors. To some extent there are parallels between these indicators of function and dysfunction with those identified by practitioners in children with SMD. As noted, Michael exhibits some characteristics of poor sensory modulation; for Michael, however, there are fewer concerns related to limbic region function than difficulty mediating attention. Importantly, there are noted differences between humans and animals, and any extrapolations between the two must be hypothetical until further work is done.

Sensory Modulation and Arousal

Arousal is often found in neurophysiology texts to be tied to wakefulness and consciousness. The literature on disorders of sensory modulation uses terms linked with arousal *(arousal, hyperarousal, hyperverbal, quiet, compliant)* to describe sensory modulation deficits, indicating a behavioral link. Arousal, or cortical activation, is a function of the reticular formation; it is dependent on sensory input. Activation of the cortex by the reticular formation (Fig. 6-5) is critical in that it changes the receptivity of cortical sensory neurons to sensory input that comes in through individual sensory system pathways. Importantly, the reticular formation is also linked with reduced sensory responsivity, such as that seen in inhibition of pain pathways (Siegel & Sapru, 2015). Thus, logic tells us that the modulation of sensory input has a relationship with arousal.

The reticular formation is a diffuse system that runs through the brainstem. In its role of regulating arousal and consciousness, it receives input from every major sensory pathway and projects to the cortex (both directly and via nonspecific thalamic nuclei) to maintain arousal levels. The presentation of new or novel stimuli increases reticular activation of the cerebral cortex; removal of sensory input decreases cortical activation

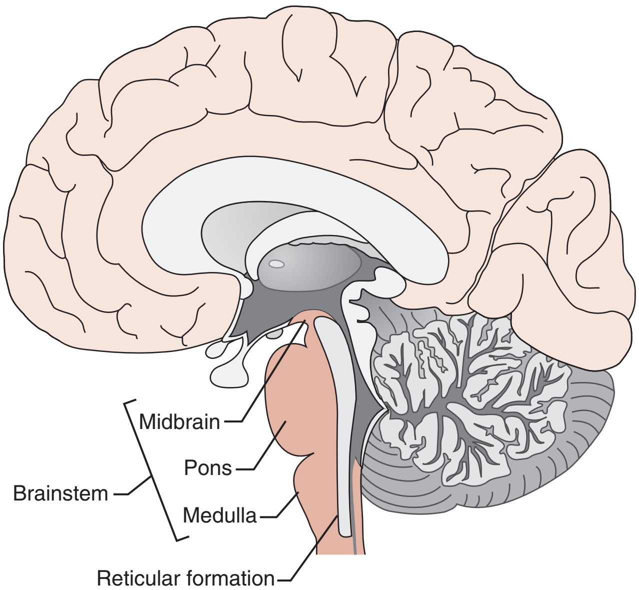

FIGURE 6-5 The reticular formation runs throughout the brainstem, forming a network of fibers and nuclei that widely influence CNS function. It receives input from every sensory system, and from other regions of the brain. Efferent fibers influence postural tone; other connections influence visceral, autonomic, and endocrine activity, as well as arousal activity and consciousness.

and leads to a gradual decrease in wakefulness. Sleep, however, is not simply a result of the withdrawal of input; instead, it results from an interaction among several neurotransmitter systems with their cell bodies in regions of the reticular formation and the hypothalamus. In response to novel or challenging stimuli, the cholinergic neurotransmitter pathways to the cortex are responsible for arousal and attention to input and motivation. Histamine plays a role in arousal and motivation, and serotonin acts to produce decreases in arousal and sleep.

With regard to SMD, practitioners have looked to the relationship between optimal arousal levels and the production of an adaptive interaction. Thinking back to Michael, his teacher may have been concerned about his arousal level because he did not contribute to classroom discussions, and she questioned whether he was processing environmental information. Kimball (1999) pointed out that moderate arousal produced an ideal adaptive environmental interaction, but over-arousal led to behavioral disorganization, anxiety, and potentially negative responses. The concept of optimal levels of arousal to function has roots in the work of Hebb (1949, 1955); within the framework of optimal arousal, we balance performance and enjoyment (called hedonic tone) in our drive for homeostasis (Kerr, 1997). Although it is clear now that sensory input to the reticular formation regulates arousal, this relationship was less clear years ago when original investigators proposed that stimulus intensity was related to performance and that it was the intensity of input that regulated arousal level. Both of these conceptualizations identified an inverted U curve relationship between arousal and performance and stimulus intensity. Such a relationship is depicted in Figure 6-6. Later work by Berlyne (1960, 1971) expanded on this concept to include other qualities of sensation as role players in the modulation of arousal. He further suggested that optimum arousal was linked to limbic and ANS functions and that there may be individual differences in tonic arousal levels and "arousability."

Kerr (1990, 1997) proposed a more complex relationship between arousal and performance that depends on how each individual interprets the positive or negative tone associated with arousal. In Kerr's model, individuals are viewed as arousal seeking or avoiding, depending on whether they find increased arousal to be a pleasant or unpleasant experience. According to Apter's (1984) reversal hypothesis, something that had been viewed as pleasant can turn into

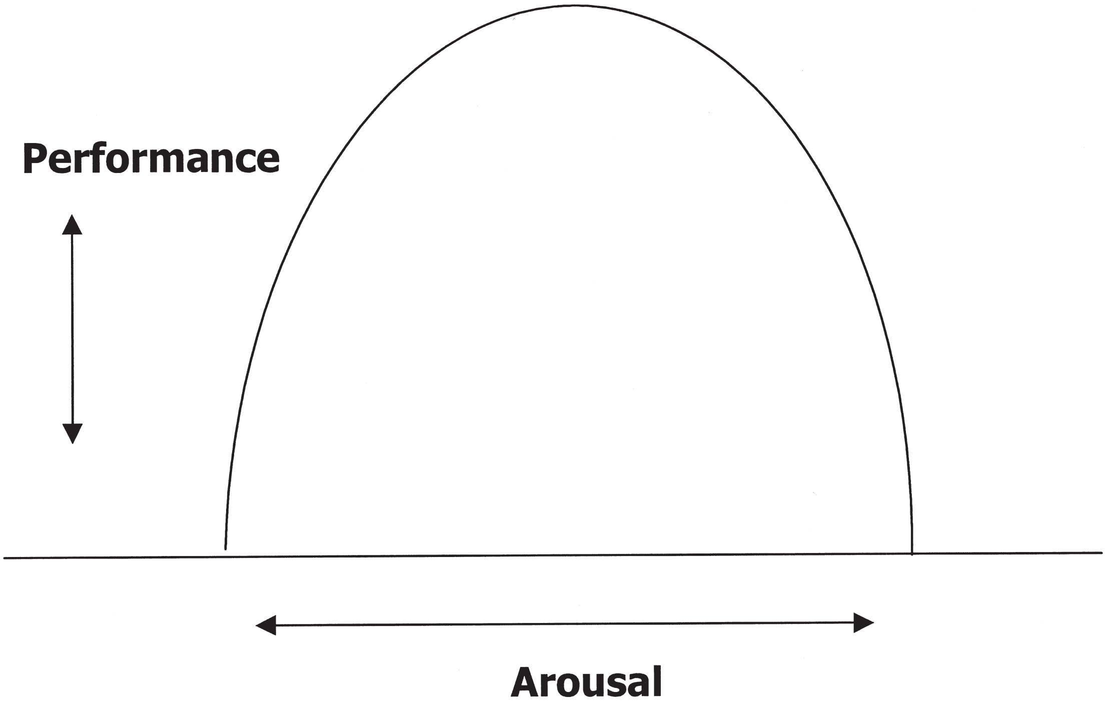

FIGURE 6-6 Proposed relationship between arousal and performance.

something unpleasant and, potentially, anxiety provoking. Reversals may be precipitated by an environmental stimulus, our own frustration at not being able to perform to expectations, or that we have simply had enough and shift from enjoyment to boredom or fatigue (Kerr, 1997). Importantly, highly arousing tasks can be viewed as pleasant, and high arousal does not necessarily interfere with performance; performance is linked with both arousal and our own interpretation of how pleasant that arousal state is. Although Kerr used this theory to understand performance in sport, such a reversal hypothesis is intriguing to consider for children with SMD who appear to shift from under-responsive and SS/craving to over-responsive and sensory avoiding. Again, considering Michael, earlier accommodations for Michael had included movement and deep pressure breaks to improve his attention and information processing. This suggests that although Michael may appear often to have lower arousal, movement may provide the input he needs to reach the optimal arousal level for learning.

Research related to the two primary dimensions associated with emotional experience, valence and arousal, also may be useful to consider. Valence is seen as bipolar, reflecting negative to positive emotion; arousal is unipolar based on the intensity of input (Recio, Conrad, Hansen, & Jacobs, 2014). In recent research using words with positive and negative valence and high and low arousal effects, Recio and colleagues found that subjects processed words more quickly if they held a positive valence, regardless of their arousal effect. However, the emotional effects were strongest when extremes of valence were combined with high arousal input. Although this research is not specifically about sensory modulation, it suggests that sensory input perceived as strongly positive (high positive valence) that is highly arousing (jumping very high on a trampoline; riding in a fast ride; watching a fast-paced movie; receiving a firm, fast rubdown with a towel) will engender the strongest emotional response.

Although it is well accepted that arousal is a function of sensory input, the link to sensory modulation is indirect. Clearly, arousal and modulation are not the same, although practitioners have used the terms *over-aroused* and *over-responsive* interchangeably. Children who have over-responsiveness to sensory input have a

PRACTICE WISDOM

Clinical reports have suggested that, for some children, over-responsiveness to sensory input leads to "shutdown." Kimball related this to ANS changes that include cardiac irregularities, changes in blood pressure, and a nervous system that "cannot respond in normal ways" (Kimball, 1976, 1977). More recently, Porges (2007) also has described autonomic shutdown, reflected in reduced parasympathetic inhibition and increased sympathetic activity. Although specific links to sensory modulation are not available, Kimball further suggested that reducing novel stimuli in the environment and decreasing the intensity and variety of input can be used as therapeutic tools to bring arousal back to the optimal range (Kimball, 1999).

limited ability to modulate input; they also often find themselves over-aroused.

Children who display under-responsivity to sensory input appear to be under-aroused. For these children, novel, intense stimuli may result in a higher arousal level and more adaptive environmental interaction. As with many of the potential links between CNS function and SMD, this area continues to warrant investigation.

Sensory Modulation and Serotonin Neurotransmission

There has been a move to examine the potential role of neurotransmitters in individuals with SMD. But we should take caution: If our ability to attach behaviors associated with SMD to specific CNS sites is limited, our ability to do the same with specific neurotransmitter systems is even more limited. As with anatomical structures, the study of transmitters has largely taken place in animals. Often studies done in humans are drug studies, suggesting that the nervous systems under investigation were, in some way, impaired. Understanding central neurotransmitter function through the measurement of peripheral references, such as transmitter metabolites in urine, is complicated by the fact that many transmitters are also present in the periphery, and, as such, metabolites in the urine may reflect peripheral as well as central activity. Nonetheless, alterations in CNS neurotransmitters, notably serotonin (5HT), *may* be tied to defensiveness, and, as such, they bear at least a cursory look.

Serotonin is made from the amino acid precursor tryptophan, and dietary intake of tryptophan can influence central levels of the transmitter. The overall number of central 5HT neurons is limited, but the projections are widespread; virtually all areas of the brain receive 5HT inputs (Bear et al., 2015). Such widespread connections implicate 5HT in many CNS functions and the expression of many behaviors and disorders. In fact, alterations in the 5HT system functions have been linked with many psychiatric disorders (i.e., major depression, seasonal affective disorder, obsessive-compulsive disorder) (Jaiswal, Mohanakumar, & Rajamma, 2015), as well as ASD, schizophrenia, potential sensory impairments, and aspects of motor incoordination (Kepser & Homberg, 2015). The 5HT link with ASD is well established, such that high prenatal and early developmental 5HT levels are associated with autistic-like behaviors (alterations in social interaction, communication, and the presence of repetitive behavior) using animal models (Veenstra-VanderWeele et al., 2012; Yang, Tan, & Du, 2014). It has been difficult to utilize this information in diagnosis and treatment of psychiatric disorders, however, as there is no adequate clinical measure of 5HT activity. Furthermore, it is important to note that multiple neurotransmitters are involved in perception and behavior. Thus, attributing any behavioral response to sensation to a single neurotransmitter is difficult.

Ongoing investigations of the 5HT system indicate a role for serotonin in loudness dependence of auditory evoked potentials (AEP), where loudness dependence reflects changes in the AEP based on the intensity of the stimulus. Weak 5HT activity (reflected in strong loudness dependence) has been found in individuals with psychiatric disorders noted earlier, and it is reversed after treatment with medications that are 5HT agonists, such as selective serotonin reuptake inhibitors (SSRIs) and lithium (Juckel, 2015). Investigators suggest this and other findings implicate 5HT in auditory sensory processing.

Interestingly, "sensory processing sensitivity" (SPS), considered a personality trait by Aron and Aron (1997), has been paralleled with alterations in the genetics of the serotonin system, specifically to the presence of a genetic variant of the serotonin transporter that influences 5HT actions in the nervous system (Homberg, Schubert, Asan, & Aron, 2016). Individuals with SPS, and those with this 5HT alteration, are more sensitive to environmental input, and at risk for the development of emotional disorders. Homberg and colleagues suggested that in animals with similar variations in the 5HT system and adults with SPS there are differences in sensory and attention networks leading to more intense sensory processing and a higher susceptibility to overstimulation. Although the specific link between SPS and alterations in the 5HT system remain to be delineated, these investigators suggested that study of variations in the serotonin system, something that must utilize animal models, may be useful to our understanding of sensory sensitivity.

The study of neurotransmitters is an intriguing one. They are, of course, linked with behavior. In fact, it would be safe to say they are all linked to behaviors of some sort. The specificity of this linking, however, presents some difficulty because there are simply too many unknown factors. Thus, further study of 5HT, the behaviors with which it is associated, *and* the relationship of these behaviors to SMD is needed before sound hypotheses can be formulated.

Stress and Modulation

One additional aspect of the relationship between sensory modulation and the limbic system deserves attention. Clinicians have long suspected that stress can amplify tactile or sensory defensiveness, and recently there has been increased research on these and related topics. Responses to events perceived to be threatening trigger activity in complex neurobiological systems, with the goal of self-preservation. One such system is the hypothalamic-pituitary-adrenal (HPA) system, supporting the release of cortisol. The HPA response to stress begins with release of corticotropin-releasing factor or hormone (CRF or CRH) from the paraventricular nucleus (PVN) of the hypothalamus. CRH travels to the anterior pituitary, leading to the release of adrenocorticotropin hormone (ACTH). ACTH, released into the circulation, travels to the adrenal cortex and leads to the release of cortisol (Bear et al., 2015). This response to stress requires a few minutes of time. Cortisol release is self-limiting in a typical nervous system; once released, it helps the body mount a fight-or-flight response to the stressor, but it also inhibits the release of CRH. Often cortisol levels in blood or saliva are measured as a means of quantifying physiological response to a stressor.

The other system linked with the stress response is the SNS. It too is mediated by outputs from the periventricular region of the hypothalamus. SNS responses to stress result in increases in heart rate and blood pressure, the release of glucose, and decreased blood flow to the gut. These responses rely on the activity of epinephrine and norepinephrine in the periphery, and they are paralleled by norepinephrine responses centrally. Central release of norepinephrine comes from a brainstem nucleus, the locus coeruleus, and supports increased arousal, focused attention, and increased vigilance (Gunnar & Quevedo, 2007), all designed to support the fight, flight, or flee response to the stressor.

These stress response systems involve limbic-cortical circuits, including the amygdala, hippocampus, and areas of the prefrontal cortex (Gray & Bingaman, 1996; Gunnar & Quevedo, 2007). Gunnar and Quevedo (2007) indicated that the amygdala is of particular importance in the regulation of CRH, and the prefrontal cortex in conjunction with the hippocampus play a role in analysis of the stressor and threat appraisal.

Activation of the anxiety system, similar to Gray's behavioral inhibition system (1982), results in avoidance behaviors. The anxiety system is put into action when the expectation of an event is negative. Thus, in any situation, we all have certain expectations of what will occur. We expect a hug from a friend to feel good and a shot to be only slightly painful. If the friendly hug turns into an uncomfortable squeeze or the injection has a burning quality not previously experienced, then our expectation does not match the real situation, and we find ourselves with increased arousal and anxiety. Gray stated that if a match occurred between expected and actual input, the behavioral inhibition system was not activated and general behavior was not altered. If a mismatch occurred, the behavioral inhibition system was activated and took control of behavior, leading to increased arousal and attention to incoming stimuli, often producing anxiety. This system has been linked with serotonin function and activity in the septohippocampal region (Gray, 1987).

If one accepts the concept of limbic involvement in sensory modulation, then stress behaviors may play a role in the manifestation of sensory over-responsiveness. When incoming and expected inputs are mismatched, Gray's behavioral inhibition system takes over, leading to increased arousal and attention to the sensory stimuli, perhaps resulting in a defensive response. These concepts of sensory modulation remain hypothetical, however, and require considerably more study.

HERE'S THE POINT

- The limbic system functions to support the intake and processing of sensation, as well as in the attachment of emotional significance and memory to sensation. Dysfunction in limbic processing has been linked with increased sensory responsivity, aggression, and emotionality.
- The reticular system mediates arousal level and is dependent on sensory input to accomplish this role. Optimal arousal is task-dependent and may be influenced by stimulus intensity.
- Sensory "shutdown" may reflect reduced parasympathetic and increased SNS activity in response to an overwhelming environment.
- Alterations in aspects of serotonin system function have been of interest to scientists investigating sensory sensitivity.
- Stress may moderate behavioral responses to environmental stimuli but additional research is needed to fully understand this relationship.

Sensory Modulation Disorders

As noted earlier, sensory modulation disorders can be seen across different sensory systems and are manifested in varied ways. Here we will focus on those more commonly recognized modulation disorders within the somatosensory and vestibular systems (refer to Chapter 4, Structure and Function of the Sensory Systems). We look briefly at other sensory systems as well, acknowledging that less is known about these disorders.

The focus in this section is on children whose primary concern is that of sensory modulation. Although modulation disorders have been identified in conjunction with disorders such as ASD and ADHD, they have importantly been documented in children without other diagnoses. The work of Reynolds and Lane (2008); van Hulle, Schmidt, and Goldsmith (2012); and Miller and colleagues (2012) support this. Reynolds and Lane documented three distinct cases of children with SOR and no additional diagnosis, and van Hulle and colleagues indicated that more than 50% of children with SOR in their study (n = 970) failed to meet criteria for other recognized childhood psychiatric diagnoses. The work of Miller and colleagues also indicated that although there is considerable overlap between children with ADHD and children with SMD, there are clear differences in sensory responsivity, both behaviorally and physiologically, as well as on measures reflecting emotion and attention. We will return to the coexistence of modulation disorders with ASD and ADHD at the end of this section.

Tactile Defensiveness

Considering potential links to CNS structures and functions, we now look at modulation dysfunction that has been associated with specific sensory systems. In this section, we present information on both *observable behaviors* and suggested *neurophysiological links*. The earliest identified, and most often discussed, is tactile defensiveness. In 1964, Ayres proposed a "provisional theory," based in part on earlier observations of Head (1920), to explain a clinical syndrome composed of deficits in tactile defensiveness, distractibility, and increased level of activity. Expanding on these ideas, Ayres (1972) described the two tactile systems as a continuum rather than a strict dichotomy. They interacted "to provide a continuum of information and response with a need-for-defense interpretation and reaction at one end of the continuum and a discriminative interpretation and discrete response at the other end" (p. 214; Fig. 6-7). Ayres hypothesized that tactile defensiveness was the result of an imbalance between discriminative interpretation and need for defense. She generalized from a protopathic-epicritic continuum to an anterolateral-dorsal column continuum (Ayres, 1964, 1972). According to Ayres (1972), tactile defensiveness occurred when the discriminative dorsal column medial lemniscal (DCML) system failed to exert its normal inhibitory influence over the anterolateral system. Therefore, light touch

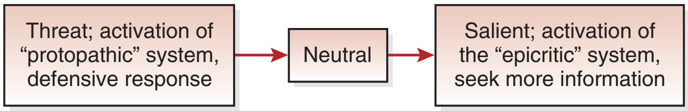

FIGURE 6-7 Ayres proposed that the protopathic (anterolateral) pathways and epicritic (discriminative) pathways functioned as a continuum. When we perceive touch as a threat, it activates our protective responses, such as withdrawal or aggression. As our perception of touch moves from threat toward neutral and beyond, we can use touch to explore the environment.

evoked protective, escape-like behavior and strong emotional responses. She hypothesized:

> The tactile defensive response, and other defensive responses to nociceptive qualities in sensory stimuli, represents an insufficient amount of the inhibitory component in a functional system designed to monitor a certain type of impulse control. Thus, the behavioral response system designed for protection and survival predominated over a system designed to allow the organism to respond to the spatial temporal qualities of the tactile stimuli. (Ayres, 1972, p. 215)

Ayres (1964) also suggested that adrenaline (epinephrine), released from the SNS during stress, played a role in the behavioral manifestations of tactile defensiveness in that the reticular activating system was sensitive to the effects of adrenaline and the DCML pathway was not. Ayres theorized that anxiety was both a cause and an effect of the predominance of the protective system and that the problem was self-perpetuating. Furthermore, a child chronically controlled by the protective system would be offered little opportunity for appropriate environmental exploration, and this might lead to delays in perceptual-motor development.

As early as 1972, Ayres recognized that the gate control theory of Melzack and Wall (1965) "unified" various historical perspectives on the duality of the tactile system. She proposed that the gate control theory provided a conceptual model for tactile defensiveness. Briefly stated, this theory suggested that "gate" neurons present in the substantia gelatinosa of the spinal cord controlled the passage of impulses to the CNS. Control of these gate cells was influenced both by incoming tactile inputs and by cortical influences (Fig. 6-8). Tactile inputs carried in large A-beta fibers commonly associated with touch-pressure and other inputs mediated by the DCML pathway activated the gate cells, which, in turn, prevented the transmission of pain to the CNS.

In contrast, inputs mediated by small A-delta and C (pain) fibers inhibited the gate cell. Thus, because the "gate is open" when the gate cell is inhibited, transmission of pain impulses was permitted. Importantly, cortical influences, such as anxiety, attention, and anticipation, as well as sensory input regarding other channels, also mediate gated activity. All of these played a role in determining whether the gate cell was activated (gate closed) or inhibited (gate opened) and, therefore, whether pain transmission could proceed (Melzack & Wall, 1965).

Ayres (1972) believed that the provision of specific (discriminative) tactile and proprioceptive stimuli would activate the DCML system to "close the gating mechanism" so as to block the protective response to touch and diminish associated increased levels of activity and distractibility. Moreover, she believed that tactile stimuli that elicited a defensive response inhibited the gate cell, thereby permitting transmission of stimuli to the CNS and resulting in a defensive response. Deep touch-pressure and other sensations mediated by the dorsal column seemed to result in gate cell activation, decreasing transmission of defense-eliciting stimuli and, thereby, diminishing the defensive response. These hypotheses also explained the ability of previous stimuli, moods, and so forth, to influence the responses of a child with tactile defensiveness. These factors would be a component of the descending cortical influences on the gate, whereby stressful states, for example, might result in gate cell inhibition and, thus, permit transmission of defense-eliciting stimuli.

Unfortunately, some aspects of the gate control theory have not been confirmed by research, and others are poorly understood and controversial. For instance, no actual gate neurons have been found in the spinal cord, and the mechanism of action of large afferent fibers influencing pain transmission and central mediation of pain has been shown to be different (Moayedi & Davis,

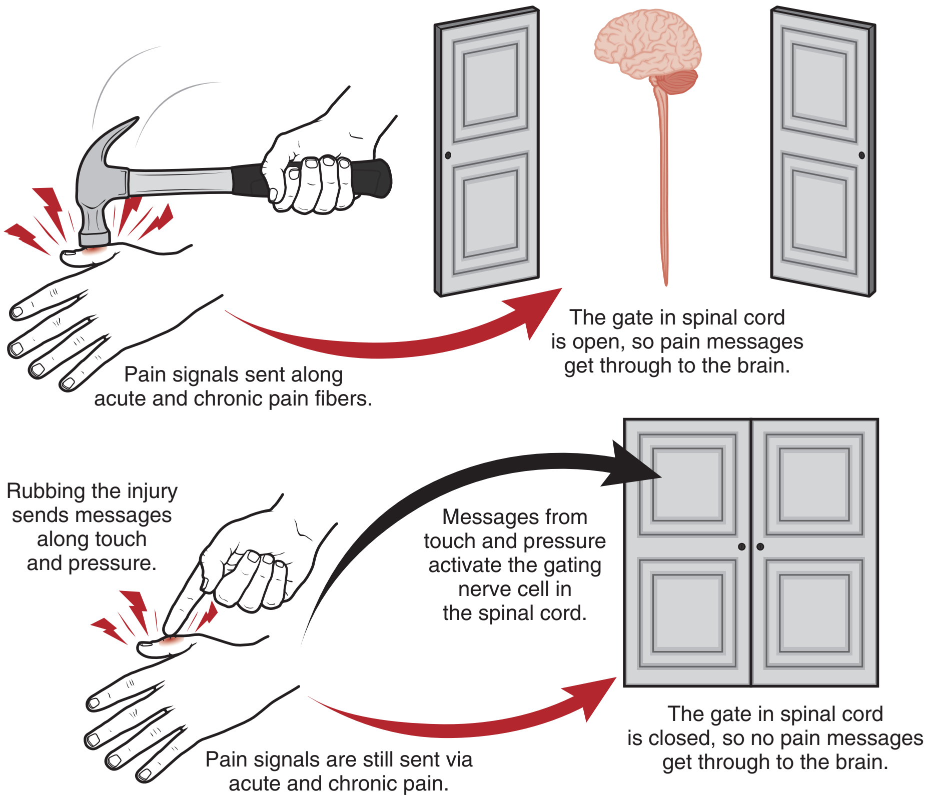

FIGURE 6-8 In their gate control theory, Melzack and Wall proposed that gate neurons in the spinal cord mediated the transmission of pain impulses to the brain. It was thought that the gate neurons were influenced by incoming touch or higher brain regions. Spinal level gate neurons have not been identified, but this theory is still foundational for our understanding of pain transmission.

2013). However, descending central pain controls exist, and it is likely that stimulation of the dorsal column will lead to pain relief (Moayedi & Davis, 2013).

In 1983, Fisher and Dunn published a review of pain control theories, including perspectives on the gate control theory of Melzack and Wall (1965) and evidence of inhibitory pain pathways. An important contribution of Fisher and Dunn (1983) was the recognition that the reduction of tactile defensiveness would not lead to improved tactile discrimination. Rather, they stressed that tactile defensiveness and poor tactile discrimination were separate disorders of tactile processing and not two ends of the same continuum; both tactile defensiveness and poor tactile discrimination could, and often did, occur in isolation (Fisher & Dunn, 1983).

One year earlier, Larson (1982) had hypothesized that tactile defensiveness was the result of a filtering deficit resulting from too little inhibition. She explained the high arousal, distractibility, and defensiveness observed in children with tactile defensiveness by a lack of inhibition of irrelevant input. Fisher and Dunn (1983) subsequently suggested that the application of the phrase "lack of inhibition" to the child with tactile defensiveness was appropriate in describing the failure of higher CNS structures to modulate incoming tactile stimuli. They pointed out that "clinical descriptions of 'lack of inhibition' in children who display [tactile defensiveness] seem to be compatible with the concept that higher-level influences are not adequately modulating tactile inputs" (p. 2). Thus, they advocated the use of intervention to decrease arousal, including touch-pressure, proprioception, and linear vestibular stimulation.

Although Larson (1982) and Fisher and Dunn (1983) limited themselves to discussions of children with tactile defensiveness, their arguments could readily be applied to children with other manifestations of sensory defensiveness. Further, although Larson (1982) emphasized a lack of inhibition resulting in tactile defensiveness, she actually described an imbalance in descending mechanisms, resulting in either too little or too much inhibition. "This imbalance decreases the ability to perceive incoming stimuli from tactile and *other sensory modalities* [italics added]" (Larson, 1982, p. 592).

A great deal of research on SOR has taken place since these initial hypotheses were put forward; much of this is summarized in Chapter 16 (Advances in Sensory Integration Research: Basic Science Research). The work of Mary Schneider and colleagues (2009) provided a causal link between prenatal stress and tactile defensiveness in a primate model and linked tactile defensiveness to altered striatal dopamine activity. This link was supported in human research conducted by Keuler and colleagues (2011). These same investigators found that tactile and auditory over-responsivity (defensiveness) was heritable, influenced by prenatal environment, and correlated with negative affect and fear.

Deficits in tactile modulation have been identified in children with ADHD and children with ASD. In children with ADHD, Parush and colleagues (2007) demonstrated that tactile defensiveness was distinguishable from poor tactile discrimination relative to central processing mechanisms. This work is important for its contribution to our understanding of defensive and discriminatory mechanisms and for the support it provides for the hypothesis of altered neural inhibition put forward by Fisher and Dunn (1983). In children with ASD, sensory modulation differences have been noted generally, and tactile and auditory over-responsivity are commonly identified when individual sensory systems are examined (Tomchek & Dunn, 2007).

Tactile defensiveness is a problem, in large part, because of inappropriate behaviors that accompany it. Tactile defensiveness may be identified by a meaningful collection of behaviors, such as:

- Avoidance of touch
  - Avoidance of certain styles or textures (e.g., scratchy or rough) of clothing or, conversely, an unusual preference for certain styles or textures of clothing (e.g., soft materials, long pants, or sleeves)
  - Preference for standing at the end of a line to avoid contact with others
  - Tendency to pull away from anticipated touch or from interactions involving touch, including avoidance of touch to the face
  - Avoidance of play activities that involve body contact, sometimes manifested by a tendency to prefer solitary play
- Aversive responses to non-noxious touch
  - Aversion or struggle when picked up, hugged, or cuddled
  - Aversion to certain daily living tasks, including baths or showers, cutting of fingernails, haircuts, and face washing
  - Aversion to dental care
  - Aversion to art materials, including avoidance of finger paints, paste, or sand
- Atypical affective responses to non-noxious tactile stimuli
  - Responding with aggression to light touch to arms, face, or legs
  - Increased stress in response to being physically close to people
- Objection, withdrawal, or negative responses to touch contact, including that encountered in the context of intimate relationships (Royeen & Lane, 1991, p. 112)

As can be discerned from this list, defensiveness to touch potentially interferes with all occupations and roles. When a child limits food and clothing choices and resists activities, such as face and hair washing and nail clipping, basic self-care becomes a trying ordeal. Avoiding sand, refusing to walk barefoot on the grass, or needing to control play activities can negatively affect one's role as a peer or sibling player. Even the more subtle behaviors that we noted with Michael, seeming to be very quiet and not engaging with others in the classroom, impair occupational engagement and performance. These and other behaviors may disrupt classroom behavior, making learning difficult.

Beyond behaviors that are linked easily to defensive responses to touch are those that are secondary to the need to control the sensory environment. Often children with defensiveness to touch are seen as distractible and overly active as they respond to irrelevant incoming sensory input (Ayres, 1965, 1966, 1969; Bauer, 1977). It is important to note that several investigators have indicated that although over-responsivity to touch may overlap with these characteristics of attention deficit, the two disorders are distinct (S. J. Lane, Reynolds, & Thacker, 2010; Mangeot et al., 2001; Miller et al., 2012; Reynolds et al., 2009). Furthermore, Wilbarger and Royeen (1987) speculated that tactile defensiveness could be a predisposing factor for irregular emotional tone, lability, extreme need for personal space, and disruption in personal care. Scardina (1986) hypothesized that tactile defensiveness interfered with the ability to establish or maintain intimate relationships. Thus, a child or adult with tactile defensiveness may experience a myriad of secondary deficits.

Identification of tactile defensiveness is possible by looking for a meaningful *cluster* of behaviors, many of which were listed earlier. Many children dislike having their face washed and nails trimmed. These behaviors alone do not constitute tactile defensiveness. As with all disorders of sensory integration, the identification of tactile defensiveness is based on the presence of a consistent pattern (i.e., a sufficient number of aversive or negative reactions to touch) to confirm that it is, indeed, the response to touch that provides the basis of the reaction. This is particularly important when we consider the affective or emotional overlay that may occur with tactile defensiveness.

Aversive Responses to Vestibular and Proprioceptive Inputs, Gravitational Insecurity, and Vestibular and Proprioceptive Under-Responsiveness

Poor modulation within the vestibular system also has been identified. The vestibular system is thought to be a primary organizer of sensory information (Ayres, 1972, 1978, 1979). The vestibular system coordinates movement of the body and eyes in response to environmental demand; it is responsible for awareness of position in space, provides a stable visual field, and contributes to physical and emotional security. According to Ayres, our relationship with gravity is more essential to our well-being than is our relationship with our mother (1979).

Fisher and Bundy (1989) indicated that over-responsivity to vestibular and proprioceptive sensations may be manifested in two ways:

> *Aversive responses* to vestibular-proprioceptive inputs are characterized by nausea, vomiting, dizziness or vertigo, and other feelings of discomfort associated with autonomic (sympathetic) nervous system stimulation. *Gravitational insecurity* is characterized by excessive emotional reactions or fear that is out of proportion to the real threat or actual danger arising from vestibular-proprioceptive stimuli or position of the body in space. Although neither disorder is well understood, both are hypothesized to be a result of hyperresponsiveness or poor modulation of vestibular-proprioceptive inputs (Fisher & Bundy, 1989), and there is some evidence that increased sensitivity to vestibular stimulation or visual-vestibular conflict can result in motion sickness (Baloh & Honrubia, 1979) [italics added] (p. 92).

Grounded in the work of Ayres and Fisher and Bundy, May-Benson and Koomar (2007) indicated that gravitational insecurity could be linked to inadequate vestibulocerebellar interactions and potentially decreased vestibular-ocular integration, leading to increased arousal and fear responses to unexpected movement experiences. Children with gravitational insecurity fear generic, everyday movement experiences, slow or fast, particularly those that involve head movements out of the vertical. Clinicians report that children with gravitational insecurity perceive small movements to be larger than they are. Children with this disorder may avoid activities that require new body or head positions, especially when their feet cannot be in contact with the floor. Fisher (1991) suggested that gravitational insecurity was related to an inability to resolve sensory conflict and inadequate development of body scheme. Because children with this modulation disorder seem to misjudge the amount of head movement they are experiencing, it also may be that gravitational insecurity is a problem of discrimination within this system. An alternative explanation has been suggested to be inefficient proprioceptive processing because proprioception has been said to modulate vestibular inputs (Ayres, 1979). The fear caused by gravitational insecurity is basic and profound and can affect emotional and behavioral development. Seemingly simple tasks, such as getting into and out of a car or stepping down off a curb, present anxious moments for individuals with gravitational insecurity. Of particular concern for these individuals is backward space, and, as such, they avoid activities such as swinging on swings.

Aversive responses to, or intolerance of, movement is the reaction we feel when we become car-, plane-, or seasick. It is characterized by strong feelings of discomfort, nausea, vomiting, or dizziness after movement that activates the semicircular canals (i.e., angular acceleration). This disorder may result from faulty modulation of inputs to the semicircular canal. Alternatively, aversive reactions to movement may result from an inability to resolve sensory conflict among visual, vestibular, and proprioceptive inputs (Fisher, 1991).

Aversive responses to movement may not appear during or even directly after an activity. Children showing aversive responses to movement may have difficulty interpreting the sensory input and may respond several hours later with a negative reaction. Fisher and Bundy (1989) and Fisher (unpublished data) described an individual with whom they had carried out an in-depth interview and vestibular testing. She was described as experiencing "sensory overload" or "sensory disorientation" after a period of visual-vestibular stimulation that included visual-vestibular conflict. Fisher (1991) described this client's response as follows:

> Approximately 3 hours after stimulation, the subject began to experience the feeling that her head, arms, and legs had become detached from her body and were floating in space. When she attempted to walk on a level surface, she felt as if she were walking on an uneven, unpredictable surface. Sometimes the surface would seem to be higher than she expected it to be, and sometimes the ground would be lower than she expected it to be. (p. 90)

Thus, an inability to resolve movement, proprioception, and visual input had a strongly disruptive effect on this individual's internal body scheme. Under-responsivity to movement is seen in children such as Michael, in this case, in conjunction with under-responsivity to proprioception. Michael seeks activities that provide movement and proprioceptive sensations in order to obtain what he considers to be an optimal level of arousal and attention in the classroom and at home.

Clinicians have debated the existence of an SMD related strictly to proprioception that appears to resemble under-responsiveness in that it is characterized by behaviors designed to obtain a great deal of proprioceptive input (Blanche & Schaff, 2001). Thus, children may hit, bang, bump, or fall on purpose. They may appear very aggressive in their interactions, and their movements may seem clumsy. Blanche and colleagues developed and pilot-tested an observation tool for proprioceptive functions intended to be used with other clinical observations of proprioceptive function (the Comprehensive Observation of Proprioception, Blanche, Bodison, Chang, & Reinoso, 2012). Using an exploratory factor analysis, they identified four proprioceptive factors (muscle tone and joint stability, proprioceptive seeking, postural control, motor planning); the seeking provides initial support for the suggestion that proprioceptive modulation deficits exist. Whether this is a specific disorder or a reflection of other sensory integrative problems continues to require further clinical and empirical investigation.

Vestibular and proprioceptive modulation deficits have the potential to interfere with occupational performance in many ways. When children show over-responsivity to vestibular input, they generally avoid many types of movement. Fearing movement through space, infants and toddlers engage in diminished environmental exploration and gross motor activity. As preschoolers, children with vestibular modulation deficits may become tense and anxious on playground equipment, avoid rough and tumble play, or become easily nauseated when riding in a vehicle. School-age children may avoid amusement parks, camp activities, and sports. Vestibular and proprioceptive modulation deficits may lead to a poor sense of position in space and movement through space and result in behaviors such as pushing, crashing, and falling.

Sensory Modulation Dysfunction in Other Sensory Systems

In addition to these somewhat classic examples of specific SMD that have been under study for several years, behavioral and physiological evidence has documented auditory modulation deficits (Chang et al., 2010), and clinical evidence has suggested that over-responsiveness may be a factor in the visual system as well. Children with auditory modulation disorders may cover their ears when in the cafeteria or grocery store, where sound bounces off of hard surfaces. They might also have difficulty paying attention to the teacher or their seat work if they have over-responsiveness to a busy visual environment. Many clinicians document taste and smell sensitivity, and it has clearly been identified by some investigators in children with autism (e.g., A. E. Lane, Molloy, & Bishop, 2014). Observations of a broader construct of sensory modulation disorder would be very consistent with the work of McIntosh, Miller, Shyu, & Hagerman (1999) and fit well with the concept of a general SMD. Careful documentation of behaviors that appear to reflect modulation deficits in these sensory systems—and examination of the underlying neuroscience correlates of the behaviors—is needed. Suggestions for intervention with clients who have SMD can be found in Chapter 12 (The Art of Therapy), Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), and Chapter 14 (Distilling Sensory Integration Theory for Use: Making Sense of the Complexity), where the art and science of intervention are presented along with different models for treatment.

Sensory Modulation Disorder in Children with Additional Diagnoses

Sensory modulation has been identified as a "stand-alone" disorder, but also it has been linked with other neurodevelopmental disorders, such as ASD and ADHD. Investigators have examined sensory modulation in conjunction with behavior and participation, stress responses, and ANS responses to sensation in children with ASD and ADHD. We will look briefly at the research along these lines, and more information can be found in Chapter 16 (Advances in Sensory Integration Research: Basic Science Research).

Autism Spectrum Disorder

Sensory modulation in children with ASD is complex, with reports of both over- and under-responsivity. The Sensory Profile (SP) and the Short Sensory Profile (SSP) have been used most commonly to identify sensory modulation disorders; the SP provided the first formalized identification of sensory modulation disorders in children with ASD (Kientz & Dunn, 1997). Although this initial work did not show a link with severity of autism, later work by several investigators (Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson et al., 2008; Kern et al., 2007; A. E. Lane et al., 2014; Watson et al., 2011) has indicated that differences in sensory modulation do correlate with autism severity and, in some studies, with mental age (Baranek et al., 2006; Leekam, Nieto, Libby, Wing, & Gould, 2007).

Links between inadequate sensory modulation and stress responses also have been established. Children with ASD were noted to show reduced SNS responses to sensory challenge along with behavioral and emotional over-responsivity (Schoen, Miller, Brett-Green, & Nielsen, 2009). Later work suggested two response patterns: a high level of tonic SNS activity coupled with high responsivity to sensory challenge, and lower SNS activity coupled with lower responses to sensory challenge (Schoen, Miller, Brett-Green, Reynolds, & Lane, 2008). Further, SOR has been linked with anxiety in toddlers with ASD (Green, Ben-Sasson, Soto, & Carter, 2012). The complexity of this link in ASD is emphasized by Corbett, Schupp, Levine, and Mendoza (2009) with the finding that some aspects of sensory processing associate with elevated morning cortisol whereas others associate with lower morning cortisol.

There is some indication that differences in sensory processing in children with ASD may show specific characteristic patterns. Patterns on the SP are different for children with ASD compared with children with ADHD and to children developing typically (Ermer & Dunn, 1998). Tactile and taste or smell over-responsivity has been documented (Wiggins et al., 2009) and linked with stereotyped behaviors. Ausderau and colleagues (2014) also identified a range of sensory subtypes, linking them with child characteristics (i.e., gender, age factors, and autism severity) and family characteristics. Lane and colleagues (Lane et al., 2010) have worked to develop a typology that more fully characterizes sensory modulation deficits in children with ASD. Their most recent work examined SP scores along with verbal IQ, autism severity, age, and gender. Through this study, they identified four sensory clusters: *sensory adaptive,* reflecting children with no clear sensory modulation deficits; *taste/smell sensitive,* reflecting extreme taste or smell sensitivity, with poor auditory filtering and sensory-seeking or under-responsive behaviors; *postural inattentive,* reflecting extreme scores for the low energy weak items, with poor auditory filtering and SS or under-responsivity; and *general sensory modulation deficits,* which included movement sensitivity (Lane, Molloy, & Bishop, 2014). Interestingly, in this study they also found a relatively large proportion (37%) of children in the sensory adaptive group, indicating no clear modulation deficits. This finding differs from those of others (c.f. Tomchek & Dunn, 2007), indicating that up to 92% of children with ASD may have concomitant sensory modulation deficits. Lane and colleagues suggested this may be the result of differences in sampling.

Sensory modulation differences in children with ASD also have been linked with aspects of function, although the relationships continue to need clarification. Baker and colleagues (Baker, Lane, Angley, & Young, 2008) suggested there were relationships between maladaptive and emotional or behavioral problems and the SSP patterns of under-responsivity or seeking, auditory filtering, and low energy/weak. Similarly, poor academic, behavioral, and emotional performance have been linked with sensitivity to touch, auditory filtering difficulty, and under-responsivity or seeking (Ashburner, Ziviani, & Rodger, 2008). Sensory avoiding, a quadrant in the Dunn model, interferes with occupational engagement and participation (Little, Sideris, Ausderau, & Baranek, 2014). Ben-Sasson and colleagues (2008) took a somewhat different approach with young children with ASD and found three broad groups of children: those with a low frequency of behaviors indicative of poor sensory modulation on the Sensory Profile, those with mixed frequency, and those with high frequency of behaviors indicative of poor sensory modulation; negative emotions, anxiety, and depressive symptoms were found more commonly in the high frequency group, whether the sensory response patterns indicated over- or under-responsivity. Recent work with preschool-aged children with ASD uncovered a strong link between sensory processing patterns and receptive and expressive language. In this study (Tomchek, Little, & Dunn, 2015), when children showed less auditory or visual sensitivity and characteristics consistent with the low energy/weak category, they had increased language skills; children with hypo-responsivity and taste or smell sensitivity also had decreased language skills. Sensory-seeking distractibility interfered with social behavior as well as fine and gross motor skills; adaptive behavior was negatively impacted by tactile and movement sensitivity, taste and smell sensitivity, and SS.

Baranek, Boyd, Poe, David, and Watson (2007) developed a performance tool to identify sensory modulation disorder, suggesting that parent report tools may be insufficient. Using their tool, they investigated sensory sensitivities in children with ASD, as well as other disorders, finding that SOR appears to be linked with mental age for children with ASD as well as with more general developmental delay. These investigators also identified sensory under-responsiveness to auditory input in their study group. Under-responsiveness was substantiated in children with ASD (Ben-Sasson et al., 2009) and, for some children, found to coexist with SOR (Ben-Sasson et al., 2007; Lane, Reynolds, & Thacker, 2010).

Attention Deficit-Hyperactivity Disorder

Sensory modulation has been documented in children with ADHD, with initial studies indicating that there were fairly global sensory differences between children with ADHD and children developing typically (Dunn & Bennett, 2002; Miller, Nielsen, & Schoen, 2012; Yochman, Parush, & Ornoy, 2004). Although children with ADHD were characterized as having difficulty processing auditory, tactile, emotional, and behavioral information related to sensation and showing SS, along with difficulty with adaptive responses to sensation, emotional reactivity, and inattention or distractibility, a systematic review indicated that there was insufficient evidence for clear subtypes (Ghanizadeh, 2011). The deficits in sensory modulation have been shown to be related to behavioral concerns. Similar findings were reported by Shimizu, Bueno, and Miranda (2014) in a Brazilian sample.

SOR has been noted in some children with ADHD, and it may play a role in teasing apart features of this disorder (Mangeot et al., 2001; Reynolds, Lane, & Gennings, 2009). Children with both ADHD and SOR (ADHD+SOR) show greater anxiety than either children developing typically or children with ADHD but no SOR (ADHD-SOR). They demonstrate higher cortisol responses and inefficient SNS recovery following sensory challenge (S. J. Lane, Reynolds, & Thacker, 2010; Reynolds et al., 2009). Looking somewhat more broadly, children with ADHD and SMD also differ from children developing typically and children without SMD on measures of SNS function, somatic complaints, adaptability, and aspects of anxiety or depression (Miller et al., 2012).

HERE'S THE POINT

- Ayres likened the neural processes underlying tactile defensiveness to those defined by Melzack and Wall, relative to the gate control theory of pain. Although the spinal level gate neuron has not been identified, there is evidence for descending pain control elicited by deep pressure input.
- Many behaviors linked with tactile defensiveness reflect the need to control the environment.
- Gravitational insecurity (GI) and aversiveness to movement reflect different modulation deficits within the vestibular system. GI is seen as fear of movement and fear of moving the head out of upright; aversiveness to movement is an intolerance to movement.
- Poor proprioceptive modulation has been less well defined but some research supports proprioceptive seeking as a possible modulation concern.
- Sensory modulation deficits are well established in children with autism, with indicators supporting different subtypes or subcategories. Research indicates that one subgroup of children with autism shows adaptive or typical sensory modulation, whereas other subgroups continue to be refined.
- Some children with ADHD demonstrate sensory modulation deficits, reflected in SOR as well as SS. When SOR is identified in this group of children, it has been linked to anxiety.

Summary and Conclusions

In summary, SMD is complex and multidimensional, and yet our knowledge has grown regarding this disorder through the past several years. When any sensory input is not modulated in an expected way, the behavior that results is "out of step" with what is needed for an adaptive environmental interaction. For some children, disorders of modulation are linked to disruptive behaviors, whereas for others, such as Michael, who was presented at the beginning of the chapter, SMD is paralleled by withdrawal and poor registration. Poor modulation has ramifications, both within the nervous system (e.g., affecting attention, arousal, and modulation of other inputs) and in the outside world because it results in the production of behaviors that do not match environmental demand or expectation. Research has provided sufficient information that we know modulation disorders exist in the absence of other comorbidities, but also in addition to diagnoses such as ASD and ADHD. Although researchers continue to unravel the neural links that underlie poor modulation, more needs to be done in this area.

Where Can I Find More?

Sensory modulation, and its impact on participation and occupation, have been studied by many investigators. Looking for additional information on the impact of disorders of modulation is perhaps best served by identifying the area of occupation about which there is concern. Here are some recent examples. Please note this is far from an all-inclusive list!

Child Participation

Mische-Lawson, L., Foster, L., Lawson, L. M., & Foster, L. (2016). Sensory patterns, obesity and physical activity participation of children with autism spectrum disorder. *American Journal of Occupational Therapy, 70*(1), 7005180070. doi:10.1111/j.1467-7687.2009.00882.x.Better

Piller, A., & Pfeiffer, B. (2016). The Sensory Environment and Participation of Preschool Children with Autism Spectrum Disorder. *Occupational Therapy Journal of Research (Thorofare NJ), 36*(3), 103–111. doi:10.1177/1539449216665116

Parent Participation

DaLomba, E., Baxter, M. F., Fingerhut, P., & O'Donnell, A. (2017). The effects of sensory processing and behavior of toddlers on parent participation: A pilot study. *Journal of Occupational Therapy, Schools, & Early Intervention, 10*(1), 27–39. doi:10.1080/19411243.2016.1257968

Toileting

Bellefeuille, I. B., Schaaf, R. C., Polo, E. R., Beadury, I., Schaaf, R. C., & Ramos, E. (2013).

Occupational therapy based on Ayres Sensory Integration in the treatment of retentive fecal incontinence in a 3-year-old boy. *American Journal of Occupational Therapy, 67*(5), 601–606. doi:10.5014/ajot.2013.008086

Eating

Engel-Yeger, B., Hardal-Nasser, R., & Gal, E. (2016). The relationship between sensory processing disorders and eating problems among children with intellectual developmental deficits. *British Journal of Occupational Therapy, 79*(1), 17–25. doi:10.1177/0308022615586418

References

Apter, M. J. (1984). Reversal theory and personality: A review. *Journal of Research in Personality*, *18*, 265–288.
Aron, E. N., & Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, *72*(2), 345–368.
Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American Journal of Occupational Therapy*, *62*, 564–573. doi:10.5014/ajot.62.5.564
Ausderau, K. K., Furlong, M., Sideris, J., Bulluck, J., Little, L. M., Watson, L. R., . . . Baranek, G. T. (2014). Sensory subtypes in children with autism spectrum disorder: Latent profile transition analysis using a national survey of sensory features. *Journal of Child Psychology and Psychiatry*, *55*, 935–944. doi:10.1111/jcpp.12219
Ayres, A. J. (1964). Tactile functions: Their relations to hyperactive and perceptual motor behavior. *American Journal of Occupational Therapy*, *18*, 6–11.
Ayres, A. J. (1965). Patterns of perceptual-motor dysfunction in children: A factor analytic study. *Perceptual and Motor Skills*, *20*, 335–368.
Ayres, A. J. (1966). Interrelationships among perceptual-motor functions in children. *American Journal of Occupational Therapy*, *20*, 288–292.
Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities*, *2*, 160–168.
Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.
Ayres, A. J. (1978). Learning disabilities and the vestibular system. *Journal of Learning Disabilities*, *11*, 18–29.
Ayres, A. J. (1979). *Sensory integration and the child*. Los Angeles, CA: Western Psychological Services.
Baker, A. E. Z., Lane, A., Angley, M. T., & Young, R. L. (2008). The relationship between sensory processing patterns and behavioural responsiveness in autistic disorder: A pilot study. *Journal of Autism and Developmental Disorders*, *38*, 867–875. doi:10.1007/s10803-007-0459-0
Baloh, R. W., & Honrubia, V. (1979). *Clinical neurophysiology of the vestibular system*. Philadelphia, PA: F.A. Davis.
Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. *American Journal of Mental Retardation*, *112*(4), 233–245. doi:10.1352/0895-8017(2007)112[233:HSPIYC]2.0.CO;2
Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory experience questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry*, *47*(6), 591–601.
Bar-Shalita, T., & Cermak, S. A. (2016). Atypical sensory modulation and psychological distress in the general population. *American Journal of Occupational Therapy*, *70*, 1–9.
Bar-Shalita, T., Deutsch, L., Honigman, L., & Weissman-Fogel, I. (2015). Ecological aspects of pain in sensory modulation disorder. *Research in Developmental Disabilities*, *45–46*, 157–167. doi:10.1016/j.ridd.2015.07.028
Bar-Shalita, T., Vatine, J. J., & Parush, S. (2008). Sensory modulation disorder: A risk factor for participation in daily life activities. *Developmental Medicine and Child Neurology*, *50*(12), 932–937. doi:10.1111/j.1469-8749.2008.03095.x
Bauer, B. (1977). Tactile-sensitive behavior in hyperactive and non-hyperactive children. *American Journal of Occupational Therapy*, *31*, 447–450.
Bear, M. F., Connors, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain* (4th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.
Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Carter, A. S., Kadlec, M. B., & Dunn, W. (2007). Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. *American Journal of Occupational Therapy*, *61*, 584–592.
Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Kadlec, M. B., & Carter, A. S. (2008). Sensory clusters of toddlers with autism spectrum disorders: Differences in affective symptoms. *Journal of Child Psychology and Psychiatry*, *49*, 817–825.
Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*(1), 1–11. doi:10.1007/s10803-008-0593-3
Ben-Sasson, A., Soto, T. W., Heberle, A. E., Carter, A. S., & Briggs-Gowan, M. J. (2017).

Early and concurrent features of ADHD and sensory over-responsivity symptom clusters. *Journal of Attention Disorders*, *21*, 835–845. doi:10.1177/1087054714543495

Ben-Sasson, A., Soto, T. W., Martínez-Pedraza, F., & Carter, A. S. (2013). Early sensory over-responsivity in toddlers with autism spectrum disorders as a predictor of family impairment and parenting stress. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *54*(8), 846–853. doi:10.1111/jcpp.12035

Berlyne, D. E. (1960). *Conflict, arousal, & curiosity*. New York, NY: McGraw-Hill.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York, NY: Appleton-Century-Crofts.

Blanche, E. I., Bodison, S., Chang, M. C., & Reinoso, G. (2012). Development of the Comprehensive Observations of Proprioception (COP): Validity, reliability, and factor analysis. *American Journal of Occupational Therapy*, *66*(6), 691–698. doi:10.5014/ajot.2012.003608

Blanche, E. I., & Schaff, R. C. (2001). Proprioception: A cornerstone of sensory integration intervention. In S. S. Roley, E. I. Blanche, & R. C. Schaff (Eds.), *Understanding the nature of sensory integration with diverse populations* (pp. 109–124). San Antonio, TX: Pro-Ed.

Bruneau, E. G., Jacoby, N., & Saxe, R. (2015). Empathic control through coordinated interaction of amygdala, theory of mind and extended pain matrix brain regions. *NeuroImage*, *114*, 105–119. doi:10.1016/j.neuroimage.2015.04.034

Cermak, S. (1988). The relationship between attention deficits and sensory integration disorders (Part 1). *Sensory Integration Special Interest Section Newsletter*, *11*, 1–4.

Chang, M. C., Parham, L. D., Blanche, E. I., Schell, A., Chou, C.-P., Dawson, M., & Clark, F. (2010). Autonomic and behavioral responses of children with autism to auditory stimuli. *American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *66*(5), 567–576. doi:10.5014/ajot.2012.004242

Cheung, P. P. P., & Siu, A. M. H. (2009). A comparison of patterns of sensory processing in children with and without developmental disabilities. *Research in Developmental Disabilities: A Multidisciplinary Journal*, *30*, 1468–1480. doi:10.1016/j.ridd.2009.07.009

Corbett, B. A., Schupp, C. W., Levine, S., & Mendoza, S. (2009). Comparing cortisol, stress, and sensory sensitivity in children with autism. *Autism Research*, *2*, 39–49.

Donovick, P. J. (1968). Effects of localized septal lesions on hippocampal EEC activity in behavior in rats. *Journal of Comparative and Physiological Psychology*, *66*, 569–578.

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and Young Children*, *9*, 23–25.

Dunn, W. (1999). *Sensory Profile*. San Antonio, TX: The Psychological Corporation.

Dunn, W. (2014). *Sensory Profile*™ *2*. San Antonio, TX: The Psychological Corporation.

Dunn, W., & Bennett, D. (2002). Patterns of sensory processing in children with attention deficit hyperactivity disorder. *Occupational Therapy Journal of Research*, *22*, 4–15.

Edelberg, R. (1972). The electrodermal system. In N. S. Greenfield & R. A. Sternbach (Eds.), *Handbook of psychophysiology* (pp. 367–418). New York, NY: Holt, Rinehart, & Watson.

Ermer, J., & Dunn, W. (1998). The sensory profile: A discriminant analysis of children with and without disabilities. *American Journal of Occupational Therapy*, *52*, 283–290.

Fisher, A. G. (1991). Vestibular-proprioceptive processing and bilateral integration and sequencing deficits. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration theory and practice* (pp. 71–107). Philadelphia, PA: F.A. Davis.

Fisher, A. G., & Bundy, A. C. (1989). Vestibular stimulation in the treatment of postural and related disorders. In O. D. Payton, R. P. DiFabio, S. V. Paris, E. J. Protas, & A. F. VanSant (Eds.), *Manual of physical therapy techniques* (pp. 239–258). New York, NY: Churchill Livingstone.

Fisher, A. G., & Dunn, W. (1983). Tactile defensiveness: Historical perspectives, new research: A theory grows. *Sensory Integration Special Interest Section Newsletter*, *6*(2), 1–2.

Fowles, D. C. (1986). The eccrine system and electrodermal activity. In M. C. H. Coles, E. Dorchin, & S. W. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 51–96). New York, NY: Guilford Press.

Fried, P. A. (1972). The effect of differential hippocampal lesions and pre- and post-operative training on extinction. *Revenue Canadienne de Psychologie*, *26*, 61–70.

Ghanizadeh, A. (2011). Sensory processing problems in children with ADHD, a systematic review. *Psychiatry Investigation*, *8*(2), 89–94. doi:10.4306/pi.2011.8.2.89

Gilman, S., & Newman, S. W. (1992). *Essentials of clinical neuroanatomy and neurophysiology* (9th ed., p. 4). Philadelphia, PA: F.A. Davis.

Gothelf, D., Furfaro, J. A., Hoeft, F., Eckert, M. A., Hall, S. S., O'Hara, R., . . . Reiss, A. L. (2008). Neuroanatomy of fragile X syndrome is associated with aberrant behavior and the fragile X mental retardation protein (FMRP). *Annals Neurology*, *63*, 40–51.

Gray, J. A. (1982). *The neuropsychology of anxiety*. New York, NY: Claredon.

Gray, J. A. (1987). *The psychology of fear and stress*. New York, NY: Cambridge University Press.

Gray, T. S., & Bingaman, E. W. (1996). The amygdala: Corticotropin-releasing factor, steroids, and stress. *Critical Review of Neurobiology*, *10*, 155–168.

Green, R. H., & Schwartzbaum, J. S. (1968). Effects of unilateral septal lesions on avoidance behavior, discrimination reversal, and hippocampal EEG. *Journal of Comparative and Physiological Psychology*, *65*, 388–396.

Green, S. A., Rudie, J. D., Colich, N. L., Wood, J. J., Shirinyan, D., Hernandez, L., . . . Bookheimer, S. Y. (2013). Overreactive brain responses to sensory stimuli in youth with autism spectrum disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(11), 1158–1172. doi:10.1016/j.jaac.2013.08.004

Green, S. A., Ben-Sasson, A., Soto, T. W., & Carter, A. S. (2012). Anxiety and sensory over-responsivity in toddlers and autism spectrum disorders: Bidirectional effects across time. *Journal of Autism and Developmental Disorders*, *42*, 1112–1119. doi:10.1007/s10803-011-1361-3

Grossman, S. P. (1978). An experimental "dissection" of the septal syndrome. In *Functions of the septohippocampal system* (pp. 227–273). Ciba Foundation Symposium 58 (new series). New York, NY: Elsevier.

Gunnar, M., & Quevedo, K. (2007). The neurobiology of stress and development. *Annual Review of Psychology*, *58*, 145–173. doi.org/10.1146/annurev.psych.58.110405.085605

Hanft, B. E., Miller, L. J., & Lane, S. J. (2000, September). Towards a consensus in terminology in sensory integration theory and practice: Part 3: Sensory integration patterns of function and dysfunction: Observable behaviors: Dysfunction in sensory integration. *Sensory Integration Special Interest Section Quarterly*, *23*, 1–4.

Head, H. (1920). *Studies in neurology* (Vol. 2). New York, NY: Oxford University.

Hebb, D. O. (1949). *The organization of behavior*. New York, NY: Wiley.

Hebb, D. O. (1955). Drives and the CNS (conceptual nervous system). *Psychological Review*, *62*, 243–254.

Homberg, J. R., Schubert, D., Asan, E., & Aron, E. N. (2016). Sensory processing sensitivity and serotonin gene variance: Insights into mechanisms shaping environmental sensitivity. *Neuroscience and Biobehavioral Reviews*, *71*, 472–483.

Isaacson, R. L. (1982). *The limbic system* (2nd ed.). New York, NY: W.B. Saunders.

Jaiswal, P., Mohanakumar, K. P., & Rajamma, U. (2015). Serotonin mediated immunoregulation and neural functions: Complicity in the aetiology of autism spectrum disorders. *Neuroscience & Biobehavioral Reviews*, *55*, 413–431. doi:10.1016/j.neubiorev.2015.05.013

Juckel, G. (2015). Serotonin: From sensory processing to schizophrenia using an electrophysiological method. *Behavioural Brain Research*, *277*, 121–124. doi:10.1016/j.bbr.2014.05.042

Kepser, L.-J., & Homberg, J. R. (2015). The neurodevelopmental effects of serotonin: A behavioural perspective. *Behavioural Brain Research*, *277*, 3–13. doi:10.1016/j.bbr.2014.05.022

Kern, J. K., Trivedi, M. H., Grannemann, B. D., Garver, C. R., Johnson, D. G., Andrews, A. A., . . . Schroeder, J. L. (2007). Sensory correlations in autism. *Autism: The International Journal of Research and Practice*, *11*(2), 123–134. doi:10.1177/1362361307075702

Kerr, J. H. (1990). Stress and sport: Reversal theory. In J. G. Jones & L. Hardy (Eds.), *Stress and performance in sport* (pp. 107–131). Chichester, West Sussex, England: Wiley.

Kerr, J. H. (1997). *Motivation and emotion in sport*. New York, NY: Psychology Press Ltd.

Keuler, M. M., Schmidt, N. L., Van Hulle, C. A., Lemery-Chalfant, K., & Goldsmith, H. H. (2011). Sensory overresponsivity: Prenatal risk factors and temperamental contributions. *Journal of Developmental and Behavioral Pediatrics*, *32*(7), 533–541. doi:10.1097/DBP.0b013e3182245c05

Kientz, M. A., & Dunn, W. (1997). A comparison of the performance of children with and without autism on the sensory profile. *American Journal of Occupational Therapy*, *51*, 530–537.

Kimball, J. G. (1976). Vestibular stimulation and seizure activity. *Center for the Study of Sensory Integrative Dysfunction Newsletter* (now Sensory Integration International), July, 4.

Kimball, J. G. (1977). Case history follow up report. *Center for the Study of Sensory Integrative Dysfunction Newsletter* (now Sensory Integration International), 5.

Kimball, J. G. (1999). Sensory integration frame of reference: Theoretical base, function/dysfunction continua, and guide to evaluation. In P. Kramer & J. Hinojosa (Eds.), *Frames of reference for pediatric occupational therapy* (2nd ed., pp. 119–168). Philadelphia, PA: Lippincott Williams & Wilkins.

Kingsley, R. E. (2000). *Concise text of neuroscience*. Philadelphia, PA: Lippincott Williams & Wilkins.

Knickerbocker, B. M. (1980). *A holistic approach to learning disabilities*. Thorofare, NJ: C. B. Slack.

Lai, J.-S., Parham, D. L., & Johnson-Ecker, C. (1999). Sensory dormancy and sensory defensiveness: Two sides of the same coin? *Sensory Integration Special Interest Section Quarterly*, *22*, 1–4.

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of children with autism spectrum disorder by sensory subtype: A case for sensory-based phenotypes. *Autism Research*, *7*(3), 322–333. doi:10.1002/aur.1368

Lane, A. E., Young, R. L., Baker, A. E., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders*, *40*(1), 112–122. doi:10.1007/s10803-009-0840-2

Lane, S. J., Lynn, J. Z., & Reynolds, S. (2010). Sensory modulation: A neuroscience and behavioral overview. *OT Practice*, *15*(21), 37–44.

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience*, *4*(8), 1–14. doi:10.3389/fnint.2010.00008

Larson, K. A. (1982). The sensory history of developmentally delayed children with and without tactile defensiveness. *American Journal of Occupational Therapy*, *36*, 590–596.

Lee, A. D., Leow, A. D., Lu, A., Reiss, A. L., Hall, S., Chiang, M.-C., . . . Thompson, P. M. (2007). 3D pattern of brain abnormalities in fragile X syndrome visualized using tensor-based morphometry. *Neuroimage*, *34*, 924–938.

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders*, *37*, 894–910. doi:10.1007/ s10803-006-0218-7

Little, L. M., Sideris, J., Ausderau, K., & Baranek, G. T. (2014). Activity participation among children with autism spectrum disorder. *American Journal of Occupational Therapy*, *68,* 177–185. doi:10.5014/ajot.2014.009894

Mangeot, S. D., Miller, L. J., McIntosh, D. N., McGrath-Clarke, J., Simon, J., Hagerman, R. J., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology*, *43*, 399–406.

May-Benson, T. A., & Koomar, J. A. (2007). Identifying gravitational insecurity in children: A pilot study. *American Journal of Occupational Therapy*, *61*, 142–147.

McIntosh, D. N., Miller, L. J., Shyu, V., & Hagerman, R. J. (1999). Sensory-modulation disruption, electrodermal responses, and functional behaviors. *Developmental Medicine & Child Neurology*, *41*, 608–615.

Melzack, R., & Wall, P. D. (1965). Pain mechanisms: A new theory. *Science*, *50*, 971–979.

Merriam Webster Online. (2015). Downloaded from http://www.merriam-webster.com/dictionary/modulate

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy*, *61*(2), 135–140.

Miller, L. J., McIntosh, D. N., McGrath, J., Shyu, V., Lampe, M., Taylor, A. K., . . . Hager, R. J. (1999). Electrodermal responses to sensory stimuli in individuals with fragile X syndrome. *American Journal of Medical Genetics*, *83*, 268–279.

Miller, L. J., Nielsen, D. M., & Schoen, S. A. (2012). Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology. *Research in Developmental Disabilities*, *33*, 804–818. doi:10.1016/j.ridd.2011.12.005

Miller, L. J., & Summers, C. (2001). Clinical applications in sensory modulation dysfunction: Assessment and intervention considerations. In S. S. Roley, E. I. Blanche, & R. C. Schaaf (Eds.), *Understanding the nature of sensory integration with diverse populations*. San Antonio, TX: Therapy Skill Builders.

Moayedi, M., & Davis, K. D. (2013). Theories of pain: From specificity to gate control. *Journal of Neurophysiology*, *109*(1), 5–12. doi:10.1152/jn.00457.2012

Olton, D. S., & Gage, F. H. (1974). Role of the fornix in the septal syndrome. *Physiology and Behavior*, *13*, 269–279.

Parham, D. L., & Mailloux, Z. (1996). Sensory integration. In J. Case-Smith, A. S. Allen, & P. N. Pratt (Eds.), *Occupational therapy for children* (3rd ed., pp. 307–355). St. Louis, MO: Mosby.

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (2007). Somatosensory function in boys with ADHD and tactile defensiveness. *Physiology & Behavior*, *90*(4), 553–558. doi:10.1016/j.physbeh.2006.11.004

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology 74*(2), 116–143.

Pribram, C. (1975). Arousal, activation and effort in the control of attention. *Psychological Review*, *82*, 116–149.

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2011). *Neuroscience* (5th ed.). Cambridge, MA: Sinauer Associates, Inc.

Recio, G., Conrad, M., Hansen, L. B., & Jacobs, A. M. (2014). On pleasure and thrill: The interplay between arousal and valence during visual word recognition. *Brain and Language*, *134*, 34–43. doi:10.1016/j.bandl.2014.03.009

Reiss, A. L., Abrams, M. T., Greenlaw, R., Freund, L., & Denkla, M. B. (1995). Neurodevelopmental effects of the FMR-1 full mutation in humans. *Nature and Medicine*, *1*, 159–167.

Reiss, A. L., Lee, J., & Freund, L. (1994). Neuroanatomy of fragile X syndrome: The temporal lobe. *Neurology*, *44*, 1317–1324.

Restak, R. (1995). *Brainscapes*. New York, NY: Hyperion.

Reynolds, S., Bendixen, R. M., Lawrence, T., & Lane, S. J. (2011). A pilot study examining activity participation, sensory responsiveness, and competence in children with high functioning autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *41*(11), 1496–1506. doi:10.1007/s10803-010-1173-x

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism and Developmental Disorders*, *38*, 516–529. doi:10.1007/s10803-007-0418-9

Reynolds, S., Lane, S. J., & Gennings, C. (2009). The moderating role of sensory over-responsivity in HPA activity: A pilot study with children diagnosed with ADHD. *Journal of Attention Disorders*, *13*, 468–478.

Royeen, C. B. (1989, August). Tactile defensiveness. An overview of the construct. Paper presented at the International Society for Social Pediatrics, Brixen, Italy.

Royeen, C. B., & Lane, S. J. (1991). Tactile processing and sensory defensiveness. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 108–136). Philadelphia, PA: F.A. Davis.

Scardina, V. (1986). A. Jean Ayres lectureship. *Sensory Integration Newsletter*, *14*, 2–10.

Schneider, A., Hagerman, R. J., & Hessl, D. (2009). Fragile X syndrome—From genes to cognition. *Developmental Disabilities Research Reviews*, *15*(4), 333–342. doi:10.1002/ddrr.80

Schneider, M. L., Moore, C. F., Larson, J. A., Barr, C. S., DeJesus, O. T., & Roberts, A. D. (2009). Timing of moderate level prenatal alcohol exposure influences gene expression of sensory processing behavior in rhesus monkeys. *Frontiers in Integrative Neuroscience*, *3*, 1–9. doi:10.3389/neuro.07.030.2009

Schoen, S. A., Miller, L. J., Brett-Green, B. A., & Nielsen, D. M. (2009). Physiological and behavioral differences in sensory processing: A comparison of children with autism spectrum disorder and sensory modulation disorder. *Frontiers in Integrative Neuroscience*, *3*(November), 1–11. doi:10.3389/neuro.07029.2009

Schoen, S. A., Miller, L. J., Brett-Green, B. A., Reynolds, S., & Lane, S. J. (2008). Arousal and reactivity in children with sensory processing disorder and autism spectrum disorder. *Psychophysiology*, *45*, S102.

Schoen, S. A., Miller, L. J., & Sullivan, J. C. (2014). Measurement in sensory modulation: The Sensory Processing Scale Assessment. *American Journal of Occupational Therapy*, *68*, 522–530. doi:10.5014/ajot.2014.012377

Schoen, S. A., Miller, L. J., & Sullivan, J. (2016). The development and psychometric properties of the Sensory Processing Scale Inventory: A report measure of sensory modulation. *Journal of Intellectual and Developmental Disability*, *42*(1), 12–21. Doi: 10.31109/13668250.2016.1195490

Shimizu, V., Bueno, O., & Miranda, M. (2014). Sensory processing abilities of children with ADHD. *Brazilian Journal of Physical Therapy*, *18*(4), 343–352. doi:10.1590/bjpt-rbf.2014.0043

Siegel, A., & Sapru, H. N. (2015). *Essential neuroscience* (3rd ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. *American Journal of Occupational Therapy*, *61*(2), 190–200.

Tomchek, S. D., Little, L. M., & Dunn, W. (2015). Sensory pattern contributions to developmental performance in children with autism spectrum disorder. *American Journal of Occupational Therapy*, *69*, 6905185040. doi:10.5014/ajot.2015.018044

Van Hulle, C. A., Schmidt, N. L., & Goldsmith, H. H. (2012). Is sensory over-responsivity distinguishable from childhood behavior problems? A phenotypic and genetic analysis. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *53*(1), 64–72. doi:10.1111/j.1469-7610.2011.02432.x

Veenstra-VanderWeele, J., Muller, C. L., Iwamoto, H., Sauer, J. E., Owens, W. A., Shah, C. R., . . . Blakely, R. D. (2012). Autism gene variant causes hyperserotonemia, serotonin receptor hypersensitivity, social impairment and repetitive behavior. *Proceedings of the National Academy of Sciences*, *109*(14), 5469–5474. doi:10.1073/pnas.1112345109

Watson, L. R., Patten, E., Baranek, G. T., Poe, M. D., Boyd, B. A., Freuler, A., & Lorenzi, J. (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. *Journal of Speech, Language, and Hearing Research*, *54*, 1562–1576.

Waxman, S. G. (2010). *Clinical neuroanatomy* (26th ed.). New York, NY: McGraw-Hill.

Wiggins, L. D., Robins, D. L., Bakeman, R., & Adamson, L. B. (2009). Brief report: Sensory abnormalities as distinguishing symptoms of autism spectrum disorders in young children. *Journal of Autism and Developmental Disorders*, *39*(7), 1087–1091. doi:10.1007/s10803-009-0711-x

Wilbarger, P., & Royeen, C. B. (1987, May). Tactile defensiveness: Theory, applications and treatment. Annual Interdisciplinary Doctoral Conference, Sargent College, Boston University.

Wilbarger, P., & Wilbarger, J. (1991). *Sensory defensiveness in children aged 2–12: An intervention guide for parents and other caregivers*. Denver, CO: Avanti Educational Programs.

Yang, C.-J., Tan, H.-P., & Du, Y.-J. (2014). The developmental disruptions of serotonin signaling may be involved in autism during early brain development. *Neuroscience*, *267*, 1–10. doi:10.1016/j.neuroscience.2014.02.021

Yochman, A., Parush, S., & Ornoy, A. (2004). Responses of preschool children with and without ADHD to sensory events in daily life. *American Journal of Occupational Therapy*, *58*(3), 294–302. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15202627

CHAPTER 7

Sensory Discrimination Functions and Disorders

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Sensations are "food" or nourishment for the nervous system . . . every sensation is a form of information. . . . Without a good supply of many kinds of sensations, the nervous system cannot develop adequately.

—A. Jean Ayres

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Appraise the foundations for sensory discrimination within each sensory system.
- ✔ Recognize behaviors associated with sensory discrimination disorders across all sensory systems.
- ✔ Describe the interactions between sensory systems relative to sensory discrimination.
- ✔ Identify tools for the measurement of sensory discrimination abilities.

Purpose and Scope

The theoretical model presented in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) depicts sensory perception as a foundation for sensory discrimination, postural ocular skills, visual motor skills, and body scheme development, and all these function as a basis for the development of praxis. Using a sensory integrative framework, therapists will often assess sensory discrimination in order to understand the underlying components of praxis and praxis-related disorders. Similarly, treatment from an SI perspective does not focus on the development of discrimination skills in isolation but rather as elements of adaptive environmental interactions. It is in this context that we examine discrimination in our sensory systems.

In this chapter, we will present a bit more detail on neural connections within the sensory systems, examine foundations for discrimination within and between sensory systems, ground this information in clinical links, and take a look at assessment approaches. Some of the assessment approaches are outside the typical realm of occupational therapy and sensory integration (SI) theory but warrant inclusion here because they contribute to our understanding of the bigger picture associated with sensory processing. Intervention approaches for improving sensory discrimination are addressed in Chapter 12 (The Art of Therapy), Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), and Chapter 18 (Complementary Programs for Intervention).

Sensory Discrimination

Sensory perception involves the interpretation of sensory stimuli and the use of that interpretation as a basis for interacting with the world. The term *sensory discrimination* refers to the ability to tell two stimuli apart (Macmillan & Creelman, 2005). Although this is a relatively simple definition, the ability to discriminate is a complex neurological function that can be altered based on experience, psychological state, and the environment. Accuracy and efficiency in discrimination across all sensory systems contribute to an individual's ability to move through space, effectively interact with objects in the environment, and perform basic daily occupations such as reading, eating, and dressing, as well as fulfilling roles such as student, sibling, and friend. The role of sensory discrimination is to allow us to make quick decisions about environmental inputs that support decision-making relative to behavior. A deficiency in the ability to discriminate sensations in any sensory system, or across sensory systems, in a way that impairs occupational performance may be considered a **sensory discrimination disorder** (Miller, Anzalone, Lane, Cermak, & Osten, 2007).

Merfeld (2011) acknowledged two aspects of discrimination: detection and recognition. **Detection** refers to the ability to discriminate a positive stimulus (e.g., an auditory tone) from a null stimulus (e.g., no sound). Hearing tests usually use a detection paradigm to determine whether someone can or cannot hear at specific frequencies. **Recognition** is what we more commonly associate with discriminative capabilities, which is the ability to tell two positive (non-null) stimuli apart. For example, if an individual is exposed to two tones, one at 75 dB and one at 120 dB, auditory discriminatory functions would allow the individual to recognize which of those tones was louder. In the case of movement discrimination, a person with intact discriminatory functions would be able to recognize if he or she had moved up or down on an escalator, without visual cues. For the purposes of this chapter, the general term *discrimination* will be used to refer to the ability to tell two stimuli apart, whether or not one stimulus is null.

Discrimination occurs before conscious perception of a stimulus. Although discrimination does not require conscious effort, discriminatory functions are intimately linked with cognitive areas of attention, memory, and decision-making. Behavioral methods of assessing discrimination often require attention and cooperation on the part of the participant, which can make assessment of discriminatory abilities in children potentially difficult. Children with greater attention skills have been shown to score higher on tests of sound (linguistic) discrimination compared with children who have more difficulty maintaining their attention (Davids et al., 2011). This means that the level of attention or saliency that an individual attributes to sensations in his or her environment may affect the quality and accuracy in which those inputs are perceived and stored. In many standardized assessments of discrimination, two stimuli are presented sequentially in a trial. A comparison or judgment is made against the **short-term memory** left by the first stimulus. In daily life, the ability to identify or classify a sensory stimulus requires the comparison of that stimulus to a reference stored in **long-term memory** (Romo & de Lafuente, 2013). Because precise and efficient discrimination of sensory inputs is a prerequisite for accurate memory storage, individuals with sensory discrimination disorders may have difficulty not only with processing sensory feedback but also with the feedforward mechanisms necessary for decision-making and the motor commands used to execute those decisions (Pleger & Villringer, 2013).

Discrimination is believed to occur across all sensory systems (i.e., auditory, visual, gustatory, olfactory, tactile, proprioceptive, and vestibular), though the integration of accurate sensory information from each system is necessary for many daily life skills. For example, both tactile and proprioceptive discrimination functions contribute to the ability to type on a keyboard or manipulate a pencil for writing without a constant need for visual monitoring. Olfactory and gustatory discrimination skills are necessary for optimal flavor recognition and play a role in determining which foods we eat. The ability to move through space is heavily dependent on vestibular, proprioceptive, and visual discrimination skills. For the purposes of organizing this chapter, auditory and visual discrimination will be discussed separately, whereas chemosensations of taste and smell have been grouped together; proprioception is addressed in conjunction with both vestibular and tactile functions.

HERE'S THE POINT

- *Sensory perception* and *sensory discrimination* refer to different processes.

- The role of sensory discrimination is to guide us in decision-making regarding environmental inputs; in this way, discrimination influences behavior.
- Sensory detection and recognition are components of sensory discrimination.
- Sensory discrimination is influenced by multiple factors including attention, cognition, and memory.

Sensory Discrimination: An Illustration

CASE STUDY ■ RICKY

When he was 6 years old, Ricky was referred to an occupational therapist because of significant motor clumsiness. He could not walk through his classroom without bumping into desks or tripping over objects in his path. Although he lived only two blocks from school, he was not allowed to walk to school by himself because he could not determine when it was safe to cross the street. On the playground, he misjudged the movement of the swings, resulting in many "near misses" when he walked by children who were swinging.

Ricky had trouble finding his way around the school and did not seem to know how to use landmarks as a guide. Gym class presented real challenges. Ricky could not catch a ball unless it hit him in the chest so that he could trap it. When playing dodgeball, he was always the first eliminated.

In his classroom, Ricky was able to read as well as his peers. Printing, however, was a challenge. He had difficulty holding the pencil; it either slipped from his fingers or he gripped it so tight his hand got tired very fast. He could not keep his letters within the lines, and the size and spacing of his letters varied tremendously. Math was also difficult. When using counters to solve a problem, Ricky counted some of them more than once and some not at all.

Ricky still needed help in dressing. He put on shirts backward, and both his legs ended up in the same pant leg. He had difficulty with fasteners such as buttons and zippers. He wore slip-on shoes because he could not tie shoelaces, but sometimes he tried to put one shoe on upside down, with the sole facing up, and he could not figure out what was wrong.

Children such as Ricky are familiar to many occupational therapists, and his description fits many children with sensory integrative dysfunction. Ricky's problems are complex, likely involving poor discrimination across multiple sensory systems. We will look more carefully at these concerns as we move through this chapter.

Touch Discrimination

The tactile system encompasses a diverse and widespread set of receptors, and it includes responses that are both discriminative and protective. Here we focus on discriminative touch; the protective aspects of this system were covered in Chapter 6 (Sensory Modulation Functions and Disorders). The term **somatosensation** is used to include both touch and proprioception, and both of these senses underlie discrimination. As such, we address proprioception here relative to its contribution to skills, such as three-dimensional shape recognition, and will also address it relative to the discrimination of movement later in this chapter.

Foundations of Somatosensory Discrimination

Discrimination within the somatosensory system relies on complex interpretation of inputs from multiple skin receptors (Bear, Connors, & Paradiso, 2015; Purves et al., 2011). This system is differently organized than other sensory systems in its wide distribution of receptors designed to detect multiple features of a stimulus, such as texture, shape, force, and movement. Receptors associated with discrimination vary considerably in their characteristics; within this system are receptors with fast and slow adaptation rates, small or relatively large receptive fields, varying thresholds for activation, and varying transmission speeds for information to reach the central nervous system (CNS; Abraira & Ginty, 2013; McGlone, Wessberg, & Olausson, 2014; see Table 4-1). Our knowledge of the receptors and their processing properties comes primarily from research conducted on what is called glabrous, or non-hairy, skin, such as that on the palm of the hand. Receptors contributing to somatosensory discrimination include Meissner corpuscles, which are relatively superficial and thus very sensitive to skin indentation. It has been noted that these receptors respond to movement of texture on the skin and guide grip in their ability to detect slippage of a held object. Pacinian corpuscles lie deeper in the skin and respond to deeper touch and vibratory input; they are thought to contribute to grip and skilled tool use. Merkel cells or discs are very sensitive to edges, points, and curves, contributing to detection of form and texture. Ruffini endings are less well understood but contribute to our ability to detect movement of the fingers, a proprioceptive function (Purves et al., 2011). No other sensory system has such a diverse set of receptors. Proprioceptive sensations also come from joint receptors and muscle spindles; these receptors transduce different movement patterns and provide information about where body parts are in space and in relation to one another.

Receptors attach to fibers that project to the dorsal horn of the spinal cord and ascend to the medulla, synapsing there in either the nucleus gracilis (lower extremity fibers) or nucleus cuneatus (upper limb, trunk, neck fibers), and it is likely that some aspects of somatosensory perception begin here (McGlone et al., 2014). The pathway associated with transmitting this information from the spinal cord to the CNS, the dorsal column medial lemniscal system (DCML), was described in Chapter 4 (Structure and Function of the Sensory Systems; see Fig. 4-14). This pathway projects from these medullary nuclei to the ventral posterior thalamic nuclei, with each receptor type connecting with unique thalamic cells. At the thalamus there is further interpretation of somatosensory information (Bear et al., 2015). Projections then go to the primary sensory cortex, S-I. This region can be subdivided into Brodmann areas 3a, 3b, 1, and 2, and within each area is a map of the body: a sensory homunculus (see Fig. 4-15). The maps reflect the density of receptors in any given area of the body; as such, the hand and mouth region are very large, whereas the trunk and leg regions are relatively small. The density of receptors has been linked with their function such that those areas dense in receptors have functions that require detailed sensory information. For instance, the hand and fingers are well innervated, supporting the need for precise information from these regions to interpret input and lay a foundation for fine motor control. Similarly, the dense innervation around the lips and tongue is important for speech production and eating skills (Bear et al., 2015).

Cortical cells in S-I respond to different types of inputs, which becomes important when considering dysfunction. Area 3b appears to be a primary somatosensory reception area in that damage here impacts all aspects of somatosensory perception; in contrast, damage to area 1 leads to difficulty with texture discrimination and to area 2 with size and shape discrimination (Bear et al., 2015; Purves et al., 2011). Areas 2 and 3 play an important role in proprioceptive processing because they receive information primarily from muscle spindles and Golgi tendon organs. From S-I, information is projected to S-II, the secondary somatosensory cortex, where new sensory discriminations are thought to occur via integration of signals from both the ventral posterior lateral (VPL) nucleus of the thalamus and S-I. Additional projections go to areas 5 and 7 of the parietal lobe. Area 5 plays a role in integration of touch and proprioception, and in area 7 somatosensory information is integrated with visual inputs (see Fig. 4-7).

Somatosensory discrimination underlies our ability to use our hands to grip and manipulate tools and objects. You might hypothesize that Ricky has difficulty with somatosensory discrimination because one of his concerns is difficulty manipulating and gripping his pencil with the right amount of force. He also struggles with fasteners and tying his shoes, which may be because of poor tactile discrimination.

Skills associated with somatosensory discrimination are essential for interaction and function in everyday life. Discrimination of somatosensation involves being able to identify the spatial and temporal qualities of sensation. It encompasses skills including two-point discrimination, **stereognosis,** texture discrimination, and detection of direction of touch. Two-point discrimination, a measure of tactile-spatial acuity, is the ability to detect two distinct points on the skin, applied simultaneously. This skill is thought by many investigators to be more challenging the closer together the two points of touch lie, and in a typical nervous system the limits of this skill are paralleled by the size of the receptive field (Purves et al., 2011). Interestingly, there is some recent evidence that suggests this is inaccurate and that basic two-point discrimination testing provides an inflated view of this aspect of tactile perception. Tong, Mao, and Goldreich (2013) suggested that two-point tactile **orientation discrimination** provides a better means of determining this function. This involves being able to distinguish whether a stimulus is placed on the skin in a vertical or horizontal orientation. Stereognosis is a commonly assessed discriminative skill associated with the somatosensory system. This skill requires integration of tactile and proprioceptive inputs in three-dimensional object discrimination; stereognosis also involves visual memory, bringing us back to the importance of multisensory integration relative to functional use of sensory discrimination.

Thinking again about the difficulty Ricky has with his pencil suggests poor integration of touch and proprioception. How the hand is used in tactile exploration influences the information obtained and, as such, plays a role in the accuracy of this discriminatory skill. The ability to use one's hands to explore objects and integrate sensory input matures gradually throughout childhood (Kalagher & Jones, 2011a). Although children younger than 5 years of age appear to have the ability to use sufficient hand skills to identify objects, they do not consistently do so (Kalagher & Jones, 2011b). At 6 years of age, Ricky should be able to use tactile discrimination to support his ability to button, pull up a zipper, and tie his shoes. The report that he has difficulty with these tasks indicates that the therapist should be looking at touch discrimination as a contributing factor in Ricky's manipulation and dexterity skills.

Inadequate somatosensory discrimination was repeatedly linked with motor planning deficits in the early work of Ayres (1965, 1966a, 1966b, 1969, 1971, 1972b, 1977, 1989). As explained in Chapter 5 (Praxis and Dyspraxia), the term *somatodyspraxia* has been used to classify children who have difficulty planning and executing novel motor actions *and* who demonstrate poor body scheme or body awareness and inadequate tactile perception (Ayres, 1979, 2005). Deficits seen in children with somatodyspraxia may include poor playground skills, difficulty manipulating tools, or challenges learning to ride a bike. You may recognize many of these concerns apply to Ricky. In recent work, Mailloux and colleagues (Mailloux et al., 2011) indicated that somatodyspraxia overlapped with visuodyspraxia, forming a single factor in their analysis; this interface between visually-based dyspraxia and somatosensory-based dyspraxia requires further consideration.

Measurement of Somatosensory Discrimination

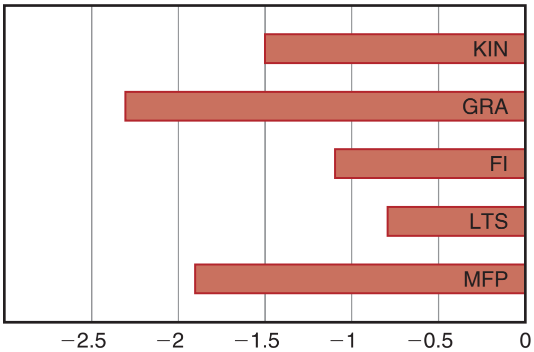
Of the tools that are currently available, tactile and kinesthetic subtests from the Sensory Integration and Praxis Tests (SIPT) offer the most comprehensive perspective on somatosensory processing in children. Thus, in spite of its age, the SIPT can provide insight into overall processing within the somatosensory system. More information on the SIPT is presented in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests). Pertinent subtests from the SIPT include the range of tactile tests, generally done with vision occluded:

- Manual Form Perception (MFP) a test of stereognosis requiring tactile shape identification
- Two-point discrimination (Localization of Tactile Stimuli; LTS) examining the ability to distinguish where a tactile stimulus is delivered on the hand or arm
- Finger identification (Finger Identification; FI)
- Graphesthesia (Graphesthesia; GRA), a test of dynamic tactile sensation in which the child replicates a design drawn on the back of the hand
- Kinesthesia (Kinesthesia; KIN), which examines conscious proprioception in asking the child to replicate a movement of the arm and hand from one point to another

Ricky was assessed using the SIPT. His standardized scores on the subtests looking at touch and proprioception are presented in Table 7-1 and Figure 7-1. Keep in mind that when scores are standardized, typical performance is reflected in scores within 1 standard deviation from the mean. The majority of Ricky's scores fall greater than 1.0 below the mean, indicating that he has difficulty with many aspects of somatosensory discrimination.

TABLE 7-1 Somatosensory Scores on the SIPT for Ricky

SUBTEST	STANDARD SCORE
MFP	–1.9
LTS	–0.8
FI	–1.1
GRA	–2.3
KIN	–1.5



SIPT subtests: KIN: kinesthesia; GRA: graphesthesia; FI: finger identification; LTS: localization of tactile stimuli; MFP: manual form perception

FIGURE 7-1 Ricky's standardized SIPT somatosensory scores. *Scores below –1.0 are considered potentially problematic, but it is important to look for clusters. Ricky scored below –1.0 on all but one of these subtests, indicating difficulty with somatosensory discrimination.*

Although the SIPT is the most thorough test of sensory discrimination available for the pediatric population, other assessments may provide insight into somatosensory processing in children such as Ricky. For example, the National Institutes of Health (NIH) Toolbox is a set of psychometrically sound performance-based and self-report measures useful in screening cognition, emotion, motor skills, and sensation across the life span (HealthMeasures, 2017). The sensation battery of the NIH Toolbox has items addressing somatosensory function, including a Brief Kinesthesia Test (based on the SIPT Kinesthesia test) and a Tactile Discrimination Test addressing texture discrimination (W. Dunn et al., 2015). Other test batteries include tactile items (e.g., the Miller Assessment for Preschoolers), but the items generally do not stand on their own.

HERE'S THE POINT

- Discrimination in the somatosensory system involves an array of receptor types.
- The density of peripheral receptors is reflected in the needed function of that region of the body.
- Somatosensory discrimination influences our ability and skill in using our hands and body for action.
- Tactile discrimination has been linked with praxis.
- Sensory integrative assessment of the somatosensory system can be largely accomplished using subtests of the SIPT.

Movement Discrimination

The ability of an individual to perceive movement of his or her body through space requires integration of information from multiple sensory systems, including the proprioceptive and vestibular systems. Accurate discrimination of sensation in these systems is necessary for the brain to generate accurate estimates of head and body position, orientation, and speed and timing of motion (Naseri & Grant, 2012).

Foundations of Proprioceptive Discrimination

The reception and transmission of proprioceptive sensation was touched on previously and presented in somewhat more detail in Chapter 6 (Sensory Modulation Functions and Disorders). Accuracy in interpreting and distinguishing proprioceptive information provides the foundation upon which individuals are able to monitor their own movement patterns, make adjustments to motor plans, and effectively execute novel and learned motor tasks (Murray-Slutsky & Paris, 2014). Proprioception contributes heavily to an individual's overall *body scheme,* the neural representation of the body used to guide motor activity (Holmes & Spence, 2004). Although body scheme is thought to represent one construct of how the brain interprets the body as a whole, research has shown that the ability to discriminate between movements of different extent using proprioception is site specific (Han, Waddington, Adams, & Anson, 2013). Athletes, for example, have been shown to have better proprioceptive ability than nonathletes in specific joints such as the knee for soccer players (Muaidi, Nicholson, & Refshauge, 2009) and the shoulder for tennis players (Boyar, Salci, Kocak, & Korkusuz, 2007). This suggests that proprioceptive discriminatory skills are developed through active engagement and use during functional tasks and that these skills are capable of being refined through practice.

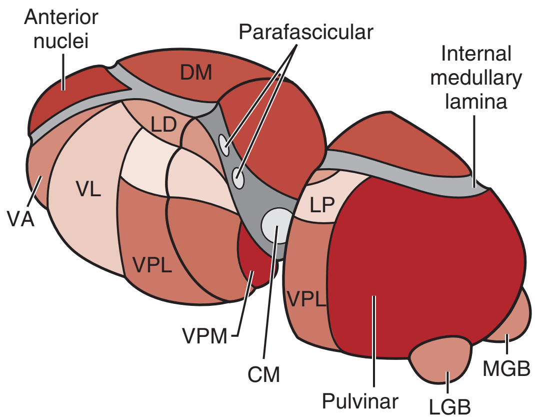


FIGURE 7-2 The thalamus has multiple nuclei. The pulvinar, ventral posterior lateral (VPL), and ventral posterior medial (VPM) receive input from multiple sensory systems and are considered integrative structures. VA: Vanteroventral; VL: Ventrolateral; CM: centromedial; MGB: medial geniculate body; LGB: lateral genculate body; LD: lateral dorsal; DM: dorsal medial; LP: lateral posterior; A: anterior.

Foundations of Vestibular Discrimination

The vestibular system also contributes heavily to movement discrimination by coding movements of the head. Discrimination of the direction and speed of movement are two functions highly dependent upon accurate vestibular processing. Poor postural control, impaired balance, and difficulties coordinating the head and eyes during movement are features often seen in individuals with deficits in vestibular discrimination (Ayres, 1972a; Miller et al., 2007). Ricky may have poor vestibular processing, given the clumsiness he shows.

As noted in Chapter 4 (Structure and Function of the Sensory Systems), vestibular hair cell receptors are located in the otolith organs and at the base of the three semicircular canals (see Fig. 4-21). These cells transduce and process linear (otolith) and angular (semicircular canals) accelerations and decelerations of the head, contributing to balance, locomotor control, and oculomotor control (Rine & Wiener-Vacher, 2013). Although the otolith receptors contribute heavily to static posture and anti-gravity positions, the semicircular canals respond to movement of the head in space and contribute most significantly to the discrimination of whole-body motion. Neurons in the vestibular and thalamic nuclei use signals from both otoliths and semicircular canals to discriminate between head translations and head tilts with respect to gravity. Thalamic nuclei, such as the pulvinar and VPL nucleus, are also thought to be important sites for multisensory integration of vestibular, visual, and proprioceptive signals (for review, see Lopez & Blanke, 2011) (Fig. 7-2).

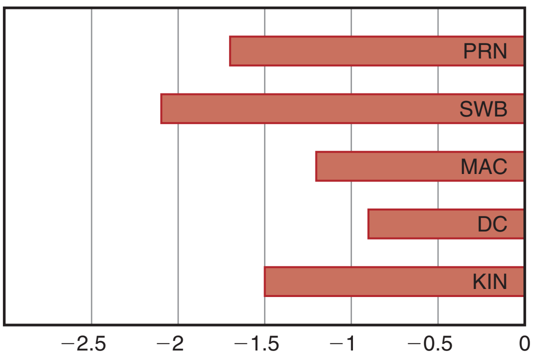
Unlike other sensory systems, no unimodal vestibular cortex (see Fig. 4-22) has been identified; rather, vestibular inputs are integrated with many other sensory signals across different cortical regions. These anatomical overlaps and functional associations are most significant between the vestibular-visual systems and the vestibular-somatosensory systems (Ferrè, Bottini, Iannetti, & Haggard, 2013). The posterior insular cortex (PIC) has been identified as playing a key role in the integration of visual and vestibular information for the perception of self-motion (Frank, Baumann, Mattingley, & Greenlee, 2014), whereas the anterior insula has been implicated as a main region for interoception and body awareness, with input coming from visual, vestibular, and somatosensory systems (Craig, 2009). Neuroimaging studies have also revealed that vestibular stimulation elicits activation of the primary somatosensory cortex, suggesting another site of anatomical overlap between the vestibular and somatosensory systems (Lopez & Blanke, 2011).

Measurement of Movement Discrimination

Measurement of proprioceptive discrimination often requires the individual to make judgment (i.e., choice) about distance after active or passive movement of a joint. As noted earlier, the KIN subtest of the SIPT provides a measure of proprioceptive discriminatory abilities. Low KIN scores along with low praxis scores (e.g., in areas of Oral Praxis [OPr] or Sequencing Praxis [SPr]) are thought to indicate poor somatopractic ability, whereas low KIN scores in combination with poor Design Copying (DC) or Motor Accuracy (MA) may indicate a poor visuopractic skill (Ayres, 1989). Another subtest of the SIPT, Standing and Walking Balance (SWB), also captures aspects of proprioception, as it includes single-foot balancing and heel-to-toe walking, with vision occluded. Ricky's scores on these SIPT subtests are presented in Table 7-2 and Figure 7-3. These findings indicate he is having difficulty with proprioceptive processing, as noted in an earlier section, and vestibular processing as indicated by the very low Postrotary Nystagmus (PRN) score.

TABLE 7-2 SIPT Subtests Related to Vestibular and Proprioceptive Processing

SUBTEST	STANDARD SCORE
KIN	–1.5
DC	–0.9
MAC	–1.2
SWB	–2.1
PRN	–1.7



SIPT subtests: PRN: post-rotary nystagmus; SWB: standing and walking balance; MAC: motor accuracy; DC: design copying; KIN: kinesthesia

FIGURE 7-3 Ricky's standardized SIPT scores related to vestibular and proprioceptive processing. *Ricky has a cluster of scores tapping vestibular and proprioceptive processing that fall below –1.0, indicating difficulty with these systems.*

The Comprehensive Observation of Proprioception (Blanche, Bodison, Chang, & Reinoso, 2012) is a recently developed measure useful for understanding body awareness, underresponsivity to proprioception, and aspects of sensory seeking. It is designed to be used in conjunction with other measures of proprioceptive function, and it offers information on such things as postural control and muscle tone. In addition, using clinical observations of prone extension, righting and equilibrium, and postural stability will add more dimension to your overall assessment. In understanding Ricky's clumsiness, you could use this tool to get more information about his postural control, muscle tone, and body awareness; this also can be accomplished using clinical observations.

Measurement of "pure" or isolated vestibular discriminatory abilities is complicated by the fact that the vestibular signals are so thoroughly integrated in the cortex. In a laboratory setting, motion stimuli can be delivered using a computerized motion platform with subjects carefully positioned in a supportive harness with a helmet; the influence on nonvestibular cues can be minimized by administering this assessment in the dark, attaching a visor to the helmet, using earplugs or white noise to mask external sounds, and using chair padding and clothing to reduce tactile stimulation or pressure on the skin (Grabherr, Nicoucar, Mast, & Merfeld, 2008; see Fig. 7-4).

This type of laboratory assessment is not practical for clinical settings nor is it necessary for the average child with sensory integrative and processing disorder. Currently, however, there are no standardized measures that clinicians can use to measure pure vestibular discriminatory abilities. What are available are measures that can inform clinicians about the integrity of the vestibular system and functional abilities known to be dependent upon adequate vestibular processing. For example, the PRN subtest of the SIPT, described in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests), provides insight into the integrity of the vestibular-ocular reflex (VOR). Although the VOR does not provide direct information about vestibular discrimination, it is a reflex that is important for visual stability and clarity when the head is moving. This test is performed by seating the child cross-legged on a

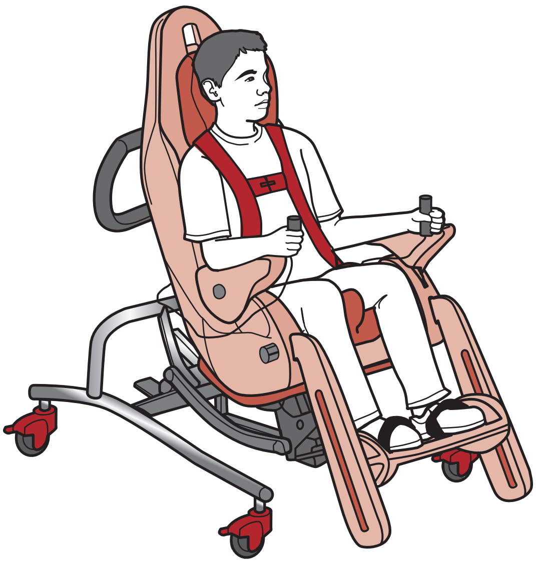


FIGURE 7-4 Measuring vestibular function and reducing the confounding effects of visual and proprioceptive input requires complex laboratory equipment. A chair such as this holds the child securely with a harness and headrest, reducing proprioceptive input. Movement testing can be conducted in the dark, and a visor or visual mask used to reduce the effect of visual inputs. A soundproof booth or room, earplugs, or white noise masks auditory input.

nystagmus board with the head tilted at an angle of 30°. The examiner turns the child counterclockwise at a constant velocity of one rotation per every 2 seconds for a total of 10 rotations in 20 seconds; a second trial is conducted in the clockwise direction. After stopping the board, the examiner can watch the child's eyes and record the duration of nystagmus (Ayres, 1989). Abnormal duration of the horizontal VOR may be an indicator of inefficient processing of information by receptors in the semicircular canals, which could contribute to deficits in movement detection and discrimination (Neveu, Jeffery, Moore, & Dakin, 2009). Ricky showed reduced PRN (Table 7-2), indicating difficulty with this aspect of vestibular discrimination.

The test of Dynamic Visual Acuity (DVA) provides a functional indirect measure of VOR and has been shown to be valid and reliable for children as young as 3 years of age. For this assessment, a visual acuity test is completed first with the child's head stationary and then again while the child's head is moved rapidly left to right (approximately 15° in each direction). The difference in acuity scores between the stationary and movement conditions provides the DVA score; a change score greater than 0.2 logMAR is indicative of semicircular canal hypofunction (Rine & Wiener-Vacher, 2013). A computerized version of the DVA is included as part of the NIH Toolbox Initiative (http://www.nihtoolbox.org).

Also part of the NIH Toolbox is the Balance Accelerometry Measure (BAM) (Rine et al., 2013), previously called the Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB; Westcott, Crowe, Deitz, & Richardson, 1994). Initially developed for adults to provide an inexpensive alternative to platform posturography (Gagnon, Swaine, Friedman, & Forget, 2004), this test is now available in a computerized format to measure standing balance in children as young as 3 years of age. Using a dual-axis accelerometer, postural sway is measured while the child is standing on a firm surface *or* high-density foam (proprioceptive manipulation); testing can be completed with eyes open *or* closed (visual manipulation). The BAM has been shown to differentiate between individuals with and without vestibular impairment, and reliability has been established (Rine et al., 2013).

Although assessment of proprioceptive and vestibular discrimination may identify or confirm the presence of atypical neurological sensory processing, it is the behavioral consequences and occupational engagement challenges, or the "end products" (Ayres, 1972a), of these discriminatory dysfunctions that are of interest to clinicians. In addition to poor balance abilities, children with poor movement discrimination may appear clumsy and frequently bump into other people or objects in the environment. They may have difficulty with using sensory information from their body (feedback) to generate appropriate feedforward mechanisms needed for precise motor execution. You may recall that body scheme is dependent on vestibular, proprioceptive, tactile, and visual input; without a good body scheme, any task in which vision is occluded or reduced, such as kicking a soccer ball while looking ahead at a teammate, will be challenging. Secondarily, individuals with a poor body scheme will often use visual monitoring to compensate for proprioceptive and vestibular deficits. Ricky provides a good example of such a child.

PRACTICE WISDOM

For children with vestibular discrimination problems, intervention may focus on enhancing the child's ability to distinguish the speed and direction of body movements while incorporating elements of postural control, ocular control, and motor planning. In SI therapy, the use of suspended equipment allows for multidirectional movement that can be controlled by the child or by the clinician. Postural extension can be challenged by having the child assume a prone position in a net swing while using active weight-bearing to propel him- or herself in a forward-and-backward motion. Discriminatory skills may be challenged at the just-right level by asking the child to change the direction or speed of the movement or to move in-time to an auditory cue (e.g., hand clap or metronome). Additional demands may be added by asking the child to sequence and time the reaching for a toy or to identify a visual target while the head and body are moving. Intervention will be maximized as the child is challenged to assume and transition among a variety of body positions in all planes and at varying speeds (Murray-Slutsky & Paris, 2014).

Vestibular and postural deficits, along with poor bilateral integration and sequencing (BIS) deficits, became a well-identified grouping in the early work of Ayres (1965, 1966b, 1969, 1971, 1972b, 1977, 1989). This grouping of concerns was verified by Mulligan in 1998 and was further substantiated by Mailloux and colleagues in 2011. Interestingly, in this more recent study, depressed PRN was also associated with this overall pattern, along with poor SWB and inadequate KIN, further indicating that these concerns are strongly associated with inadequate vestibular and proprioceptive processing.

HERE'S THE POINT

- Proprioceptive discrimination contributes to the development of body scheme and the ability to engage in and refine performance of functional tasks.
- Postural control, balance, and coordination of eye and head movements are aspects of vestibular discrimination.
- Subtests of the SIPT, including PRN, SWB, and KIN, tap into vestibular and proprioceptive discrimination; however, it is also necessary to include clinical observations to supplement these scores.
- The Clinical Observation of Proprioception provides additional information about proprioceptive discrimination that may augment more formal testing.
- Vestibular-proprioceptive discrimination deficits may be reflected in clumsiness (poor balance, bumping into people and things in the environment) and difficulty using feedforward and feedback to calibrate movement.

Auditory Discrimination

Discrimination of "What" We Hear

Auditory discrimination is most commonly defined as the ability to differentiate between similar sounds, including distinguishing between various **phonemes,** the smallest possible sounds in words. When most children learn to read, they use an alphabetic system, learning the speech sounds associated with different letters (Heilman, Voeller, & Alexander, 1996). Children who fail to develop this reading strategy are often diagnosed with phonological dyslexia, and they also may have difficulty relating phonemes to **graphemes,** the smallest distinguishing unit in written language (Blau et al., 2010). Therefore, difficulties with sound discrimination and letter-speech sound integration may lead to difficulties in both reading and writing. Children with poor auditory discrimination are also at higher risk for having specific language impairment (SLI), which is another type of phonological deficit. These children show delays in the development and mastery of normal language despite having no hearing loss or other developmental delays (Davids et al., 2011).

Although the neural circuitry underlying auditory sound discrimination is still being studied, it is believed to be comprised of two primary components. First, there is a clear sensory-specific component in which sound signals originate in the cochlea and project to the auditory cortices. The Heschl gyrus, found in the area of the primary auditory cortex near Brodmann area 41, is the first cortical structure to process incoming auditory information and has been specifically linked to abilities in pitch discrimination and detecting tonal patterns (Schneider et al., 2002; see Fig. 7-5). The second component is associated with the involuntary switching of attention from the familiar to novel or unfamiliar stimuli; this function is thought to be largely attributed to areas of the frontal cortex (Alho, 1995; Bidet-Caulet, Bottemanne, Fonteneau, Giard, & Bertrand, 2015; Dunn, Gomes, & Gravel, 2008). Distinct populations of neurons in the prefrontal cortex (PFC) have been identified that selectively encode decisions about stimulus presence and stimulus absence (Merten & Nieder, 2012); additional studies have found that neurons in the pre-motor cortices of the frontal lobe correlate closely with behavioral reports about stimulus presence or absence (de Lafuente & Romo, 2005).

Discrimination of "Where" We Hear

The auditory system, including the auditory cortex, plays a key role in discriminating not only "what" we hear but also "where" we hear

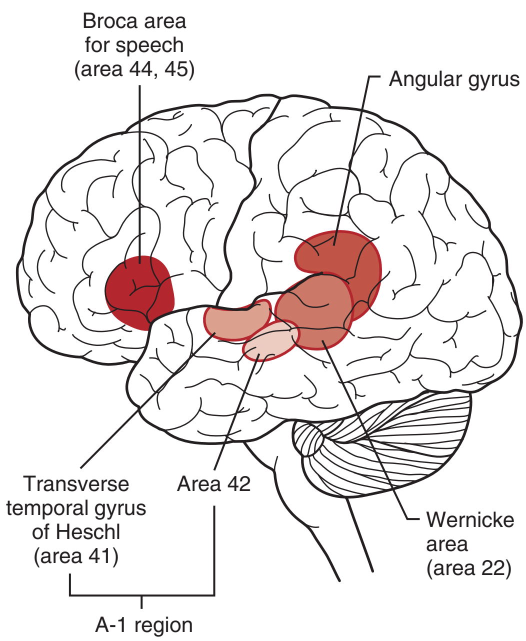


FIGURE 7-5 Cortical auditory processing begins in Heschl gyrus (near area 41) in the primary auditory cortex. Processing of sound into language involves projections from area 41 to Wernicke area (area 22) where the sound is understood. Projections from area 22 pass through the angular gyrus to project to the motor speech region of the frontal cortex, known as Broca area, or area 44, 45.

it. **Spatial discrimination** of sounds, including the location of objects in the environment, is an essential aspect of responding to many everyday situations and is considered a prerequisite skill for efficient communication and interaction in complex environments (Ahveninen, Kopčo, & Jääskeläinen, 2014). According to Ahveninen and colleagues (2014), spatial hearing has two main functions: enabling an individual to localize sound sources and to separate sounds based on spatial location. As such, different types of spatial change may be discerned, including detection of motion onset (motion-onset response), change in position of the sound relative to a stationary head position, or changes in head or body position with reference to the sound source (Getzmann & Lewald, 2012). Tasks such as reaching for a ringing phone, judging the distance of an approaching car, and focusing on a single conversation at a loud birthday party are all functional skills resulting from accurate and efficient discrimination of spatial sounds.

Unlike the generation of visual spatial information, which is limited by the individual's visual field, the auditory system is capable of registering stimuli originating from any direction, even if they are partially occluded by other objects (King et al., 2011). Given this omnidirectional capacity, auditory space is complexly mapped in terms of horizontal (azimuth) and vertical (elevation) coordinates relative to the interaural axis. Distance coordinates localize sound based on the position from the listener; sounds are measured from the center of the listener's head. The details of auditory spatial mapping are beyond the focus of this chapter.

The representation of auditory space and discrimination of sound localization is thought to be largely computed by the central auditory system. Chapter 4 (Structure and Function of the Sensory Systems) presented basic information on the central auditory pathways. From the perspective of auditory discrimination, we will highlight a few points here. Auditory nerve fibers innervate the dorsal and ventral cochlear nuclei; from these nuclei project the pathways critical for both monaural and binaural processing. Monaural pathways primarily target the contralateral inferior colliculus (IC). In contrast, the first site of binaural convergence is in the superior olivary complex (SOC), which detects and encodes for differences in both time and intensity. As noted in Chapter 4 (Structure and Function of the Sensory Systems), fibers from the SOC project to the IC, and it is here that time and sound-level information converge with each other and with monaural signals before ascending to the auditory cortex via the medial geniculate body of the thalamus (Grothe, Pecka, & McAlpine, 2010).

Imaging studies and electroencephalography (EEG) measurements have provided insight into higher level processing of auditory spatial discrimination and motion processing. Although anterior areas of the auditory cortex, such as the Heschl gyrus, appear to be responsive to phonetic changes (the "what" pathway), neuron populations in the posterior non-primary auditory cortex have been implicated in detection of spatial change (the "where" pathway). Additionally, the secondary auditory cortex, a region that includes the planum temporale, is speculated to be involved with auditory-visual-motor integration important for localizing and mirroring speech sounds and lip-reading (Jääskeläinen, 2010). The auditory cortex also plays a critical role in providing descending inputs to the IC for auditory spatial processing and spatial learning. Inactivation of these descending pathways has been shown to disrupt or modify IC neuron sensitivity to sound frequency, intensity, and location (King et al., 2011). Thus, auditory discrimination of spatial cues can be impacted by disruption in both bottom-up and top-down processing.

Measurement of Auditory Discrimination

Assessment of auditory discrimination is outside of the realm of what most occupational therapists perform. However, we will briefly cover two common approaches. The most common method used for measuring auditory discrimination abilities is **mismatch negativity** (MMN), a component of the event-related potential (ERP) to an odd stimulus in a sequence of stimuli. It involves comparing brain waves (electrical activity) elicited by a repeated standard sound with those elicited by a rarer deviant sound differing on one or more perceptual features, such as pitch, duration, or loudness (Bishop, Hardiman, & Barry, 2011; see Fig. 7-6). MMN can be used to measure functions of both the "what" and the "where" pathways, as well as auditory sensory memory (Cheour, Leppänen, & Kraus, 2000). The MMN

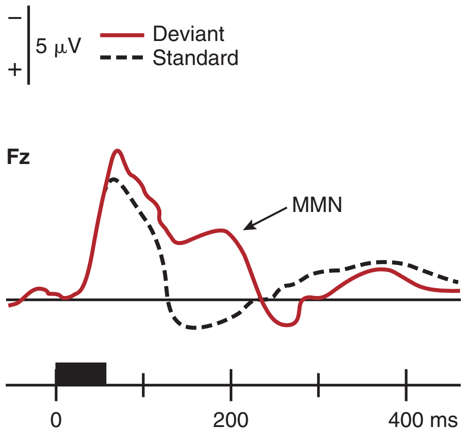


FIGURE 7-6 Mismatch negativity (MMN) recording. The dotted line shows the neural response to a standard or equivalent sound repeatedly heard; repeated administration results in habituation to the sound. The dashed line shows a typical neural response when a different or deviant sound is heard. In this situation, the response was habituating, but when the deviant sound was presented, the neural response increased again. Fz: a specific electrode site in an electroencephalogram, located in the midsagittal plane, in the region of the frontal lobe; MMN: mismatch negativity; ms: milliseconds; μV: microvolts.

can be elicited regardless of whether the subject is paying attention to the sequence. As such, it is considered advantageous over behavioral methods that require attention and cooperation from participants (Bishop et al., 2011). The earliest MMN responses have been obtained from preterm infants (CA 30–34 weeks) in response to small changes in speech stimuli (Cheour-Luhtanen et al., 1996).

Although the MMN may be ideal for measuring auditory discrimination abilities in children, it is not always available for use in therapeutic clinical settings. Auditory discrimination skills can be measured using behavioral methods, taking into consideration factors such as attention, concentration, and motivation, which may impact performance. Behavioral tests, such as the Wepman's Auditory Discrimination Test–2nd Edition (ADT™; Wepman & Reynolds, 1986), involve the experimenter reading aloud two words (e.g., "coast" and "toast") and asking the child to indicate, verbally or gesturally, whether the words are the same or different. Words may differ in a vowel or consonant, and differences may occur at the beginning, middle, or end of the word. In order to avoid visual cueing, the mouth of the examiner is covered during these types of auditory discrimination tasks.

Interestingly, studies have shown that some children can discriminate tones at an automatic level (measured by MMN), yet they perform poorly on a behavioral discrimination task with the same stimuli (Gomes et al., 2000). Dunn and colleagues (2008) suggested that these findings show that the inability to respond accurately on a behavioral auditory discrimination task, such as the ADT™, does not provide definitive information about where the processing difficulty has occurred. This is likely because behavioral tests that require a motoric response (e.g., verbal or gestural) may tap into additional neural regions, such as the parietal cortex, dorsolateral prefrontal cortex (dPFC), or striatum, that have distinct roles in perception and decision-making. Projections from the auditory cortex to the striatum in particular have been shown to drive behavioral choices during auditory discrimination tasks (Znamenskiy & Zador, 2013), whereas the dPFC appears to be recruited in decision-making tasks irrespective of the sensory modality upon which it receives information (Romo & de Lafuente, 2013).

Ricky did not show signs of poor auditory discrimination. If he had, the occupational therapist would likely have referred him to an audiologist or speech and language pathologist for additional assessment.

HERE'S THE POINT

- The auditory cortices and frontal lobe are primarily responsible for detection and recognition of auditory changes in the sensory environment.
- Auditory discrimination involves understanding both the "where" and the "what" of sound.
- Difficulty with sound discrimination has been linked with difficulties in reading, writing, and sustained attention.
- There are behavioral and neurophysiological measures of auditory discrimination; using both may result in discrepant findings.

Visual Discrimination

Within the literature, visual discrimination is described as one feature of visual perception. **Visual perception** was defined many years ago as the ability to recognize, *discriminate,* and interpret visual stimuli (Maslow, Frostig, Lefever, & Whittlesey, 1964). Maslow and Frostig, along with their colleagues, tied poor visual perception to difficulties with reading. Current literature also refers to visual perception when addressing the broader skill set that includes such things as visual attention, visual memory, and visual discrimination (Canel & Yüksel, 2015; Schneck, 2010), and it indicates that visual discrimination involves the ability to distinguish shape and formation of objects, including letters. In this section we will address visual discrimination, but we will go a bit beyond the boundaries of this aspect of visual perception and also touch on visual guidance of movement and aspects of visual cognition as they become important relative to SI.

Foundations of Visual Perception and Discrimination

As has been the case with the other sensory systems in this chapter, the basics of stimulus reception, transduction, and transmission to regions of the brain have been presented in the text already, in Chapter 4 (Structure and Function of the Sensory Systems). You may recall that the projection from the occipital lobe to the temporal lobe formed the *"what"* pathway (ventral stream), a foundation for our ability to store and recall visual forms; this pathway is associated with recognition and identification of objects. Milner and Goodale (2008) indicated that this pathway is important in identification of objects that become the goal for movement and in selecting (but not planning) a course of action for reaching the object. The pathway that projects to the parietal lobe (area 5) is considered the *"where"* pathway (dorsal stream), involved in understanding visual space, locating objects in space, and detecting movement of objects through space; this pathway is one we use to guide movements in space (Schwartz, 2010). Importantly, this pathway is associated with determining how to reach the goal object (planning) and with controlling the movements needed to reach the goal (Milner & Goodale, 2008). Processing in both pathways goes beyond parietal and temporal lobes, projecting to the prefrontal cortex, thus contributing to aspects of visual cognition (Schwartz, 2010; see Fig. 7-7).

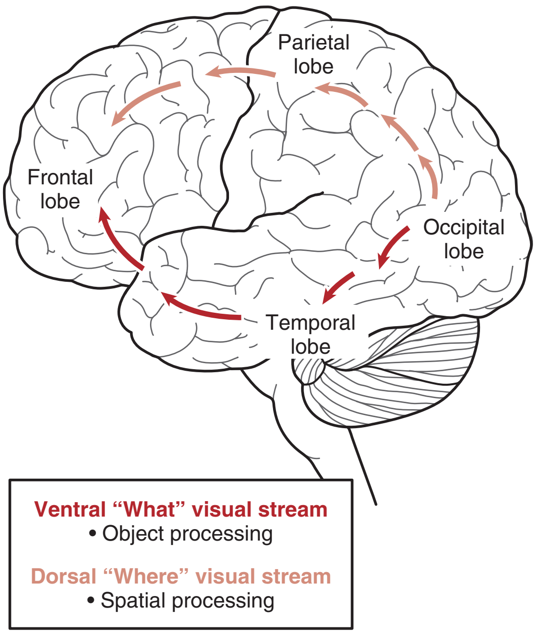


FIGURE 7-7 Projections from the visual cortex to the parietal lobe (the dorsal stream or "where" pathway) assist in functions such as understanding visual space, locating objects in space, and detecting movement of objects through space. The ventral or "what" pathway projects through the temporal lobe and is critical for recognizing and identifying objects in our environment. Both streams project to the frontal lobe.

The two streams of information must interact; for instance, we cannot guide movement through space, as in reaching for and grasping an object, without knowledge of object characteristics (for review, see Stiles, Akshoomoff, & Haist, 2013). However, skills within each system mature at different rates. Developmentally, the ventral stream, and object recognition, matures earlier than does the dorsal stream, which guides movement (Dilks, Hoffman, & Landau, 2008). These authors suggest that ventral stream skills peak at approximately 4 years of age, whereas dorsal stream skills continue to mature until at least 6 years of age.

Vision and Movement Through Space

The visual systems interface with several other sensory, motor, language, and cognitive systems as they contribute to function. Consistent with the functions noted previously for the dorsal visual stream, vision guides movement, and processing vision along with other sensory systems is crucial for praxis; this integration is important in our ability to interact with the environment in a fluid and coordinated manner (Okoye, 2005). The auditory system can compensate partially as a spatial sense when vision is lost, and it enhances vision by signaling the direction of noise, which is important in shifting attention to a speaker or warning of an approaching car. The interaction of upper body, head, and eyes is crucial to our ability to orient to sounds and sound sources in the environment. As noted earlier in this chapter, and in Chapter 6 (Sensory Modulation Functions and Disorders), visual-vestibular interactions are crucial to skills such as balance and the accurate perception of self-motion (Siegler, Viaud-Delmon, Israël, & Berthoz, 2000) as well as functions such as the VOR. Proprioceptive contributions of the eyes and neck are perceived and interpreted in the context of our head and eye position and movement, and, in conjunction with vestibular inputs, they are important in the development of body scheme. Body scheme is also dependent on information about both ongoing and intended patterns of movement that come from tactile, proprioceptive, and vestibular inputs coupled with visual information (Bolognini & Maravita, 2007; Lackner & DiZio, 2000; Maravita, Spence, & Driver, 2003). These interactions lay the foundation for postural background preparation for action and for movement through space; skills such as reach and grasp, addressed in the text that follows, are accurate because the visual system helps us aim and provides sufficient information about objects to allow for grasp. Our actions in space are accurate because the visual-spatial coordinates and the body reference coordinates are integrated. For example, Ricky was constantly bumping into things when walking, suggesting difficulty integrating knowledge of space and his own body scheme.

Reach and grasp are adaptive responses partially dependent on aspects of visual perception and reliant on input from the ventral and dorsal processing streams. Reaching requires visual and proprioceptive integration (Battaglia-Mayer et al., 2014), as well as praxis. Reach initiation relies on understanding the goal (Fig. 7-8); it is preplanned and not dependent on vision. However, visual adjustment can be made as the hand enters the field of vision, allowing for precise reach of the target (Battaglia-Mayer et al., 2014; Jeannerod, 1981; Jeannerod & Biguer,

FIGURE 7-8 Reaching is a skill that develops early in life. It relies on cortical processing of visual inputs, and integration with the processing of other sensations such as proprioception. This young child manages to locate the object in space, and program his reach while maintaining his balance in sitting.

1982). Preparing for grasp involves a complex interplay of the motor system with visual information relative to shape, size, and contours of the object (for review, see Turella & Lingnau, 2014).

Visual Cognition

As noted previously, **visual cognition** is a set of skills that goes beyond visual discrimination. Skills associated with visual cognition include visual attention, memory, and discrimination. **Visual attention**, a skill present but immature at birth (Johnson, 2013), involves alertness and vigilance and includes selective and shared attention. Consistent with the term *attention,* visual attention involves focusing the visual system on an object or target and filtering out the visual information that is not salient to the task at hand. Visual attention is believed to be foundational for visual perception, and some investigators indicate that it is crucial for tasks such as reading (Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Vidyasagar & Pammer, 2010). Visual attention, and the ability to determine what has happened and anticipate what may happen because of it, are important skills in the development of visual MA (Okoye, 2005). You might suspect that Ricky has some difficulty with visual attention given his inability to use landmarks as a guide to getting around school as well as his difficulty using counters in math. Visual memory is our ability to interpret visual information based on previous experience. It is crucial in our ability to distinguish between novel and routine stimuli and plays a role in other aspects of visual cognition (Giuliani & Schenk, 2015). *Visual discrimination,* as noted earlier, is the ability to distinguish the unique features of objects and forms such that we can identify them (Schneck, 2010). Higher-order visual-spatial abilities involve the combined abilities to recognize and remember the relationships between features within an object or design, between two or more objects, or between oneself and objects. Recent reviews indicate that regions associated with the ventral stream and higher-order processing play a role in being able to quickly recognize word shapes, which is an important aspect of reading (Wandell, 2011; Wandell, Rauschecker, & Yeatman, 2012). More complex spatial analysis may involve mentally monitoring a series of steps that transform a spatial display and then predicting the outcome. Games such as chess rely heavily on this ability. Mental rotation of objects is another component of spatial analysis. Although children can perform mental rotation at as young as 5 years of age, processing is neither efficient nor speedy, and it is influenced by such things as intelligence, gender, socio-economic status, videogame experience, and practice (Stiles et al., 2013).

Visual construction is a perceptual activity that integrates visual discrimination abilities with a motor response. Construction has a strong spatial component; accurately reproducing a two- or three-dimensional design requires grasping the spatial relationships among the parts of a design. Construction requires spatial abilities processed by the dorsal system and elementary form perception as processed by the ventral system, as well as a wide range of cognitive abilities, which may include attention, concentration, or verbal facility, depending on the task.

Drawing is a form of two-dimensional construction, involving form discrimination and form reproduction. For instance, infants can discriminate simple forms such as a square and circle early in the first year of life (Slater, Morison, &

Rose, 1983) but cannot draw a circle until 3 years of age or a square until 4 years of age (Beery & Beery, 2010). Copying a square requires drawing horizontal and vertical lines, something 3-year-old children can do, but it is several years before a child has the perceptual skills needed to analyze and draw a square using these horizontal and vertical lines. Preschool-aged children approach the task of drawing spatial patterns initially by breaking the pattern into visual "parts" and making the parts fit together to form the spatial pattern; both aspects of pattern reproduction mature through time (see Stiles et al., 2013 for review).

Handwriting, considered a visual-perceptual-motor skill, is a particularly important skill in children's daily school activities. Poor execution of the spatial aspects of writing numbers and letters leads to errors in math, illegibility, and messy homework; we see this with Ricky. Relative to handwriting, visual discrimination is what allows us to distinguish between two similar forms—for instance, a "b" and a "d"—to understand letter (shape) formation and directionality, and to determine letter and word spacing. An accomplished hand writer uses vision only for spot checks to make sure horizontal alignment and proper spacing between words is maintained, yet beginning hand writers depend on vision for guidance when learning to write. Letter formation in manuscript writing requires a spatial analysis similar to that of copying geometric forms, and copying forms at some early level of proficiency generally precedes writing (Daly, Kelley, & Krauss, 2003; Marr, Windsor, & Cermak, 2001); more current work suggests that copying and tracing both should be examined relative to handwriting (Kaiser, Albaret, & Doudin, 2009). When a child has difficulty with letter forms (Fig. 7-9), the reason for illegibility may be the poor shaping or closure of individual letters or a lack of uniformity in orientation or size.

A second class of constructional abilities requires the manipulation of objects that must be assembled to match a model (Fig. 7-10). Tasks such as these place less demand on memory and imagery; trial-and-error may be possible in finding correct solutions. In other ways, the demands for spatial cognition are similar to those in paper-and-pencil spatial tests. A simple assembly task is the copying of models of cubes as used in the testing of young children. Young children are able to stack cubes at approximately 12 months of age and can arrange them in a line by 18 months; building using both horizontal and vertical organizational strategies emerges between 3 and 4 years of age (Stiles et al., 2013; Stiles-Davis, 1988). Visual construction ability grows with age, and recent research suggests a link between visual construction, visual spatial reasoning, and the development of math skills (Casey, Pezaris, & Bassi, 2012; Verdine et al., 2014).

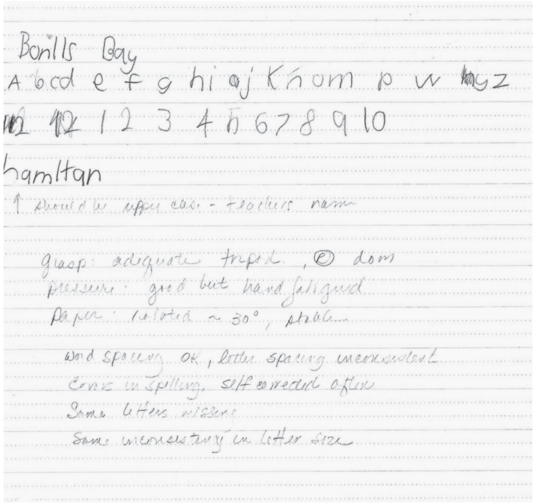


FIGURE 7-9 Poor handwriting legibility is shown here in a sample from a 9-year-old. You can see a mix of upper- and lowercase letters, inconsistency in size and spacing, missing letters, and self-corrections.

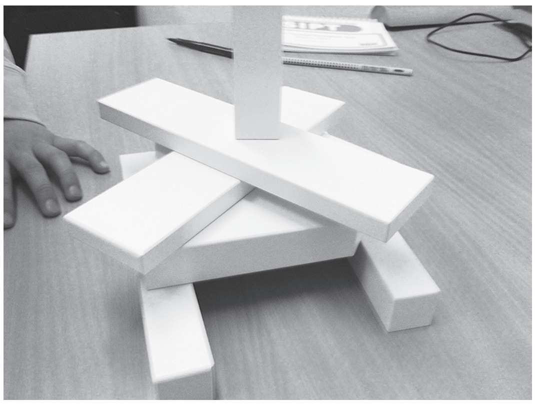


FIGURE 7-10 Part 1 of the Constructional Praxis subtest of the SIPT requires the child to build this structure in two steps, as the examiner models the building. *Photo courtesy of Therapy in Praxis Limited.*

HERE'S THE EVIDENCE

There are several investigations that have looked at the effectiveness of particular handwriting interventions. Intervention approaches vary widely and include those with a foundation in SI or that are sensorimotor in nature, those with an approach focused on perceptual-motor skills, and others that take a cognitive intervention approach. Hoy, Egan, and Feder (2011) published a systematic review of handwriting interventions. Their review included intervention studies for school-aged children with difficulties in handwriting. To be included in this review, studies were required to address students with difficulty with written output. Criteria included both treatment and control groups (randomized or nonrandomized samples) and the intervention needed to be one that could be used by an occupational therapist. Authors identified 11 studies that met the inclusion criteria. Intervention varied, but authors categorized the interventions as: relaxation with handwriting practice; sensory-based without specific handwriting practice; and cognitive or sensorimotor-based with handwriting-based practice. The amount of practice varied among studies. Authors indicated that it was not clear whether a sensory-based or cognitively based program was better, and they suggested that this might vary by the age of the child. However, the inclusion of handwriting practice was an essential component of intervention effectiveness. Importantly, a minimum amount of intervention was identified: two weekly sessions during at least 20 weeks' time. Tapping into internal motivation for writing improvement was notably important, as was working with teachers, parents, and the students themselves to establish appropriate goals. Although limited by the small number of studies and small sample sizes within each study, this study indicates that improvements in legibility are best found with practice of this skill; improvements in handwriting speed appear to require more intense intervention. Handwriting is a complex skill that involves tactile, proprioceptive, and visual processing for both the fine motor aspect of the task and the postural control required for the task. Working from a sensory integrative perspective, the provision of a strong sensory foundation lays a foundation for the development of handwriting skills, but occupational therapy intervention also must include specific practice of the skill itself.

Hoy, M., Egan, M., & Feder, K. (2011). A systematic review of interventions to improve handwriting. *Canadian Journal of Occupational Therapy, 78*(1), 13–25. doi:10.2182/cjot.2011.78.1.3

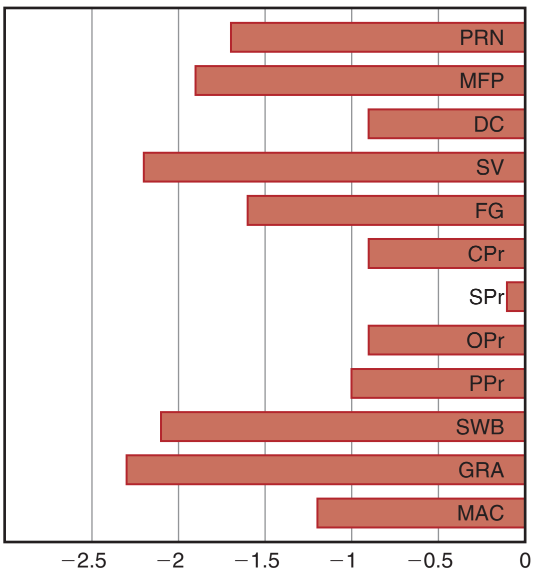
Measurement of Visual Perception and Discrimination

The SIPT offers several subtests that tap specifically into the visual perceptual skills described in this section. It also taps the visual system as it is integrated with touch and movement. Aspects of visually guided movement can be seen in subtests such as MAC, in which the child is required to trace over a line as accurately as possible. The tactile test of GRA also has a visual component, in visualizing the image drawn on the back of the hand and in guiding the replication of this image. SWB relies on visual-vestibular interactions for balance and movement on items where eyes are open. In fact, Postural Praxis (PPr), OPr, and SPr all require visual analysis of the examiner's model. Visual attention is required for all subtests in the visual perceptual domain, with Figure Ground (FG) emphasizing attention and visual analysis. Spatial analysis is also required in many of the subtests and is clearly seen in Space Visualization (SV), during which the child is required to match the location of the hole to that of the peg in the formboard, and, in later items, mental rotation of the forms to determine which one will fit. Spatial analysis is also crucial in the visual-tactile subtest MFP, in which children first match a form held in the hand with an image of the form; in part 2, they match forms using both hands. Both two-dimensional and three-dimensional visual construction are included on DC and Constructional Praxis (CPr), respectively. Ricky's scores on these subtests (Table 7-3 and Fig. 7-11) indicate difficulties with visual spatial skills, questionable visual praxis skills, and poor visual-tactile skills. His difficulties with vestibular and proprioceptive processing were noted earlier.

Using the SIPT, difficulties with aspects of visual discrimination have been repeatedly identified. In fact, Ayres coined the term

TABLE 7-3 SIPT Scores for Subtests Addressing Aspects of Visual Discrimination

SUBTEST	STANDARD SCORE
MAC	–1.2
GRA	–2.3
SWB	–2.1
PPr	–1.0
OPr	–0.9
SPr	–0.1
CPr	–0.9
FG	–1.6
SV	–2.2
DC	–0.9
MFP	–1.9
PRN	–1.7



SIPT subtests: PRN: post-rotary nystagmus; MFP: manual form perception; DC: design copying; SV: space visualization; FG: figure ground; CPr: constructional praxis; SPr: sequencing praxis; OPr: oral praxis; SWB: standing and walking balance; GRA: graphesthesia; MAC: motor accuracy; PPr: postural praxis

FIGURE 7-11 Ricky's standardized SIPT scores: Visual discrimination.

visuosomatodyspraxis to reflect aspects of praxis that were linked with visual processing (Ayres, 1989). Ayres (1969, 1972c, 1977, 1989), Mulligan (1998), and Mailloux and colleagues (2011) all identified patterns involving poor visual perception, visual-motor skill, and visual construction. The more recent work of Mailloux and colleagues (2011) with a group of children referred for sensory integrative testing defined a factor they titled Visuodyspraxia and Somatodyspraxia, which included SV, MFP, DC, and CPr, as well as PPr and Praxis on Verbal Command. A second factor also combined visual and tactile processing, that of Tactile and Visual Discrimination. This included the subtests of LTS, FG, and FI.

There are myriad of other assessments of visual perceptual and visual-motor skills, as well as individual items on developmental assessments. Assessments commonly used by occupational therapists include the following:

- Developmental Test of Visual Perception, Third Edition (Hammill, Pearson, & Voress, 2013), which looks at visual perception and visual-motor integration in children between 4 years of age and 12 years, 11 months of age.
- Beery-Buktenica Developmental Test of Visual-Motor Integration, Sixth Edition (Beery & Beery, 2010), which includes normative data on visual motor integration for those between 2 years of age and 99 years, 11 months of age.
- Test of Visual Motor Skills, Third Edition (Martin, 2006a), standardized for those from 3 years of age through 90+ years of age to assess DC.
- Test of Visual Perceptual Skills (non-motor), Third Edition (Martin, 2006b), which examines visual discrimination, memory, sequential memory, figure-ground, and closure, as well as form constancy and visual-spatial relationships in children 4 years of age through 18 years of age.
- Motor-Free Visual Perception Test-4 (Colarusso & Hammill, 2015), which assesses visual discrimination, memory, and closure, as well as spatial relationships and visual closure without the requirement of motor responses in individuals from 4 years of age to 80 + years of age.

HERE'S THE POINT

- The visual system defines both the "what" and "where" of objects and people in the environment.
- Processing in the "what" and "where" pathways is highly integrated to allow for complex skills, such as movement through space, reach and grasp, and object use.
- Visual inputs are highly integrated with auditory, tactile, vestibular, and proprioceptive inputs.
- Visual cognition is composed of skills such as visual attention, memory, and discrimination as well as spatial analysis and construction.
- Handwriting involves complex visual perceptual motor integration.
- The SIPT offer many tests for assessment of visual discrimination skills and integration of the visual system with other sensory systems.

Taste and Smell Discrimination

How and what we taste is dependent upon the integration of two chemical senses: gustation and olfaction. These two systems play a particular role in food selection, and secondarily nutrition and mealtime behaviors (Negri et al., 2012). Both systems also serve important protective functions. For example, humans have the ability to identify bitter tastes, which might indicate a food is poisonous and unsafe to eat. Humans can also discriminate the odor of edible food vs. rotten food and identify dangerous odor, such as leaked gas. Disturbances in olfactory or gustatory processing may be genetic or caused by a variety of situational factors including age, gender, use of medications, respiratory infections, hypothyroidism, and peripheral nerve damage. The term **hyposmia** refers to a reduced ability to smell, whereas **hypogeusia** refers to a reduced sensitivity to taste stimuli.

Foundations of Taste Discrimination

Genetic variation in taste receptor sensitivity gives rise to unique perceptions of certain tastes (Feeney, O'Brian, Scannell, Markey, & Gibney, 2011); the most commonly agreed upon tastes are sweetness, saltiness, sourness, bitterness, and umami. There is also evidence for a sixth taste receptor that senses *fat.* Bitterness is the most well studied taste; although there is a natural range in which bitter compounds are detected, *supertasters* perceive bitterness to a greater extent than nontasters (for a review, see Hayes & Keast, 2011). Supertasters are thought to have heightened discrimination skills; research has indicated that such individuals like and consume vegetables and potentially fruits less than other individuals (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006; Duffy et al., 2010; Negri et al., 2012; Yackinous & Guinard, 2002). In contrast, nontasters have been reported to consume more alcohol and have a greater preference for high-fat and sweet foods (Duffy, 2004). Given the influence of taster-status (e.g., supertaster vs. nontaster) on dietary food choices, taste discrimination may be important to consider in children who are picky eaters or are at risk for obesity.

Gustatory perception is based upon chemical sensitivity of gustatory receptors located on the tongue. Taste buds made up of these receptors are contained in papillae, which are the visible bumps and ridges on the surface of the tongue. Taste receptors are also found on the soft palate (see Figs. 4-27 and 4-28), pharynx, and the upper part of the esophagus. Chemicals from food interact with saliva to activate taste receptors, which generate an action potential in the gustatory afferent neuron. Three different cranial nerves (VII, IX, and X) innervate the taste buds and carry taste information to the gustatory nucleus of the solitary tract complex in the medulla. Information is relayed to the ventral posterior medial (VPM) nucleus of the thalamus before projecting to the primary gustatory cortex (frontal operculum and insula).

Taste discrimination, or coding of taste, is thought to occur at several levels. Broad taste differentiation takes place in the mouth as individual taste receptors respond selectively to specific taste stimuli (e.g., sweet, salty). A process of **population coding** is thought to occur in which each food activates a different combination of taste receptors, and it is that combination of broadly tuned receptors that is used to specify the properties of the taste stimulus and make it unique (Bear et al., 2015). Further, flavors are often the result of a combination between taste and smell, and taste response patterns are also integrated with temperature, texture, and pain signals (e.g., spicy, hot) to enhance the coding mechanism and allow humans to identify flavors and discriminate between tastes.

Foundations of Smell Discrimination

With approximately 1% of the mammalian genome being comprised of the olfactory receptor gene family, humans are capable of detecting millions of airborne odorants and discriminating between thousands of odors. The sense of smell is the oldest evolutionary sense, and, through time, each species has developed a genetic make-up that allows for a unique olfactory repertoire (Hoover, 2010). Variations in what we smell and preference for odors varies across cultures and changes through time and based on relevant experiences (Åhs, Miller, Gordon, & Lundström, 2013). Studies have shown women to be superior at tasks such as odor identification, whereas both men and women show a higher odor detection threshold and diminished ability to discriminate odors with increasing age (Ghielmini, Poryazova, Baumann, & Bassetti, 2013; Greenberg, Curtis, & Vearrier, 2013; see Fig. 4-29).

Olfactory dysfunction has been linked with mental disorders such as schizophrenia, depression, and autism, as well as with neurodegenerative disorders such as Parkinson's disease (Boesveldt et al., 2008; Cohen, Brown, & Auster, 2012; Galle, Courchesne, Mottron, & Frasnelli, 2013; Naudin et al., 2012). Although the basic neurological processes involved in odor discrimination are outlined next, there is evidence that functional odor discrimination can also be influenced by a variety of factors including mood, sleepiness, and experience (Greenberg et al., 2013).

The process of olfactory discrimination begins when air is inhaled and passes over the olfactory epithelium, a thin mucus-covered sheet of cells high up in the nasal cavity. Similar to taste buds, olfactory receptor neurons respond best to one broad class of substances. There is evidence that the topography of receptors in the olfactory epithelium is important in the discrimination of hedonic valence or "pleasantness" (Castro, Ramanathan, & Chennubhotla, 2013). Axons from primary olfactory receptor cells converge and terminate in the two olfactory bulbs. The connection is organized to form a type of odor map (Bear et al., 2015). The circuit mapping in the olfactory bulbs provides a mechanism by which odorant signals are distinguished and broadly categorized.

Although other sensory systems pass first through the thalamus before projecting to the cortex, the output axons of the olfactory bulbs have direct projections to the olfactory cortex and areas of the limbic system, such as the amygdala; this ties smell closely with aspects of emotional processing. As with taste, *population coding* is thought to play a major role in the ability to discriminate odors. Integration of these signals in unique combinations allows specific properties of odorants to be distinguished and identified (Gire et al., 2013). There is also evidence that some output cells of the olfactory bulb have specific firing patterns for given odorants. This type of **temporal coding** is thought to contribute to odor discrimination and recognition (Gire et al., 2013).

Measurement of Taster Status and Taste or Smell Discrimination

Assessing taste and smell discrimination is not typically within the repertoire of an occupational therapist. However, taster status (i.e., to determine if someone is a "supertaster") may be examined using standardized taste test strips (Indigo Instruments, Tonawanda, NY) coupled with a visual analog rating scale of taste intensity (Reynolds, Kreider, & Bendixen, 2012). Using a forced-choice paradigm, the *Sniffin Sticks* test of nasal chemosensory function uses pen-like odor-dispensing devices to deliver odorant stimuli. As noted by Hummel and colleagues (2007), *Sniffin Sticks* have been used in more than 100 published studies of olfactory function and have well-established test-retest reliability and validity.

Whether or not individuals with SI disorders need assessment and intervention for taste and smell, discrimination problems likely depends on what functional manifestations are present. A therapist may need to ask: *Is safety a concern for this child,* or *is this child's dietary behavior negatively impacted by his or her taste and smell discrimination abilities?*

HERE'S THE POINT

- Taste and smell are both protective sensory systems.

- Taste depends on processing within both the olfactory and gustatory systems.
- The perception of taste is genetically influenced, often involves the activation of multiple receptors, and influences dietary choices. Smell varies across cultures and experiences.
- Smell is the only sensory system projecting directly to limbic structures from the receptors, strongly linking smell with aspects of emotion.

Summary and Conclusions

Sensory systems are responsible both for discrimination of sensation and for modulation of input in the regulation of a response. This chapter addressed the former, sensory discrimination. The discriminative functions associated with the processing of touch, proprioceptive, vestibular, and visual input have been linked with praxis and our ability to interact with people and things in the environment. Auditory discrimination has not been studied within the framework of SI, but its contributions to our ability to map space and move through the environment makes consideration of this system important. Similarly, taste and smell have not been well represented in sensory integrative theory and yet play a role in food choice and social interaction. We have barely scratched the surface on the details of sensory discrimination in this chapter and encourage you to look into these sensory processing functions more closely.

Where Can I Find More?

Sensory discrimination is a huge topic area. By necessity, this chapter has omitted many aspects of discrimination in all sensory systems. For more in-depth information on some of the sensory systems, we suggest the following:

- Bellis, T. J. (2011). *Assessment and management of central auditory processing disorders in the educational setting: From science to practice* (2nd ed.). San Diego, CA: Plural Publishing Inc.
  - Written for clinicians, this book provides both scientific and practical knowledge related to auditory processing disorders. It includes detailed chapters on neuroanatomy as well as practical suggestions and classroom management techniques.
- Kurtz, L. A. (2006). *Visual perception problems in children with AD/HD, autism, and other learning disabilities.* London: Jessica Kingsley Publishers (JKP).
  - This book provides a comprehensive overview of vision problems in children with developmental disabilities and describes activities for strengthening children's functional vision and perceptual skills.
- Linden, D. (2015). *Touch: The science of hand, heart, and mind (unabridged MP3, CD).* Old Saybrook, CT: Tantor Audio.
  - Available in audio and text formats, this book examines how our sense of touch and our emotional responses affect our social interactions as well as our general health and development.

References

Abraira, V., & Ginty, D. (2013). The sensory neurons of touch. *Neuron*, *79*(4), 618–639. doi:10.1016/j.neuron.2013.07.051

Åhs, F., Miller, S. S., Gordon, A. R., & Lundström, J. N. (2013). Aversive learning increases sensory detection sensitivity. *Biological Psychology*, *92*, 135–141.

Ahveninen, J., Kopčo, N., & Jääskeläinen, I. P. (2014). Psychophysics and neuronal bases of sound localization in humans. *Hearing Research*, *307*, 86–97.

Alho, K. (1995). Cerebral generators of mismatch negativity (MMN) and its magnetic counterpart (MMNm) elicited by sound changes. *Ear & Hearing*, *16*, 38–51.

Ayres, A. J. (1965). Patterns of perceptual–motor dysfunction in children: A factor analytic study. *Perceptual and Motor Skills*, *20*, 335–368.

Ayres, A. J. (1966a). Interrelations among perceptual–motor abilities in a group of normal children. *American Journal of Occupational Therapy*, *20*, 288–292.

Ayres, A. J. (1966b). Interrelationships among perceptual–motor functions in children. *American Journal of Occupational Therapy*, *20*, 68–71.

Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities*, *2*, 160–168. doi:10.1177/002221946900200307

Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. *American Journal of Occupational Therapy*, *25*, 329–334.

Ayres, A. J. (1972a). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972b). *Southern California sensory integration tests*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972c). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy*, *26*, 13–18.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy*, *31*, 362–366.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1979; 2005). *Sensory integration and the child*. Los Angeles, CA: Western Psychological Services.

Battaglia-Mayer, A., Buiatti, T., Caminiti, R., Ferraina, S., Lacquaniti, F., & Shallice, T. (2014). Correction and suppression of reaching movements in the cerebral cortex: Physiological and neuropsychological aspects. *Neuroscience & Biobehavioral Reviews*, *42*, 232–251.

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain* (4th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Beery, K. E., & Beery, N. A. (2010). *Beery-Buktenica Developmental Test of Visual-Motor Integration* (6th ed.). San Antonio, TX: Pearson.

Bidet-Caulet, A., Bottemanne, L., Fonteneau, C., Giard, M. H., & Bertrand, O. (2015). Brain dynamics of distractibility: Interaction between top-down and bottom-up mechanisms of auditory attention. *Brain Topography*, *28*, 423–426.

Bishop, D. V. M., Hardiman, M. J., & Barry, J. G. (2011). Is auditory discrimination mature by middle childhood? A study using time-frequency analysis of mismatch responses from 7 years to adulthood. *Developmental Science*, *14*(2), 402–416.

Blanche, E. I., Bodison, S., Chang, M. C., & Reinoso, G. (2012). Development of the comprehensive observations of proprioception (COP): Validity, reliability, and factor analysis. *American Journal of Occupational Therapy*, *66*(6), 691–698. doi:10.5014/ajot.2012.003608

Blau, V., Reithler, J., van Atteveldt, N., Seitz, J., Gerretsen, P., Goebel, R., & Blomert, L. (2010). Deviant processing of letters and speech sounds as proximate cause of reading failure: A functional magnetic resonance imaging study of dyslexic children. *Brain*, *113*, 868–879.

Boesveldt, S., Verbaan, D., Knowl, D. L., Visser, M., van Rooden, S. M., van Hilten, J. J., & Berendse, H.W. (2008). A comparative study of odor identification and odor discrimination deficits in Parkinson's disease. *Movement Disorders*, *23*, 1984–1990.

Bolognini, N., & Maravita, A. (2007). Proprioceptive alignment of visual and somatosensory maps in the posterior parietal cortex. *Current Biology*, *17*, 1890–1895.

Boyar, A., Salci, Y., Kocak, S., & Korkusuz, F. (2007). Shoulder proprioception in male adolescent tennis players and controls: The effect of shoulder position and dominance. *Isokinetics and Exercise Science*, *15*(2), 111–116.

Canel, N., & Yüksel, M. Y. (2015). Evaluating the development of the visual perception levels of 5-6 year-old children in terms of school maturity and "draw a person" technique. *Journal Plus Education*, *12*(1), 61–78.

Casey, B. M., Pezaris, E. E., & Bassi, J. (2012). Adolescent boys' and girls' block constructions differ in structural balance: A block-building characteristic related to math achievement. *Learning and Individual Differences*, *22*(1), 25–36. doi:10.1016/j.lindif.2011.11.008

Castro, J. B., Ramanathan, A., & Chennubhotla, C. S. (2013). Categorical dimensions of human odor descriptor space revealed by non-negative matrix factorization. *PLOS One*, *8*, 1–16.

Cheour, M., Leppänen, P. H., & Kraus, N. (2000). Mismatch negativity (MMN) as a tool for investigating auditory discrimination and sensory memory in infants and children. *Clinical Neurophysiology*, *111*, 4–16.

Cheour-Luhtanen, M., Alho, K., Sainio, K., Rinne, T., Reinikainen, K., Pohjavuori, M., . . . Näätänen, R. (1996). The ontogenetically earliest discriminative response of the human brain. *Psychophysiology*, *33*, 478–481.

Cohen, A. S., Brown, L. A., & Auster, T. L. (2012). Olfaction and the schizophrenia spectrum: An updated meta-analysis on identification and acuity. *Schizophrenia Research*, *135*, 152–157.

Colarusso, R. P., & Hammill, D. D. (2015). *Motor-Free Visual Perception Test-4*. Novato, CA: Academic Therapy Publications.

Craig, A. D. (2009). How do you feel-now? The anterior insula and human awareness. *Nature Reviews Neuroscience*, *10*, 59–70.

Daly, C. J., Kelley, G. T., & Krauss, A. (2003). Brief report—Relationship between visual-motor integration and handwriting skills of children in kindergarten: A modified replication study. *American Journal of Occupational Therapy*, *57*, 459–462.

Davids, N., Segers, E., van den Brink, D., Mitterer, H., van Balkom, H., Hagoort, P., & Verhoeven, L. (2011). The nature of auditory discrimination problems in children with specific language impairment: An MMN study. *Neuropsychologia*, *49*, 19–28.

De Lafuente, V., & Romo, R. (2005). Neuronal correlates of subjective sensory experience. *Nature Neuroscience*, *8*, 1698–1703.

Dilks, D. D., Hoffman, J. E., & Landau, B. (2008). Vision for perception and vision for action: Normal and unusual development. *Developmental Science*, *11*(4), 474–486. doi:10.1111/j.1467-7687.2008.00693.x

Dinehart, M. E., Hayes, J. E., Bartoshuk, L. M., Lanier, S. L., & Duffy, V. B. (2006). Bitter taste markers explain variability in vegetable sweetness, bitterness, and intake. *Physiology and Behavior*, *87*, 304–313.

Duffy, V. B. (2004). Associations between oral sensation, dietary behaviors and risk of cardiovascular disease (CVD). *Appetite*, *43*, 5–9.

Duffy, V. B., Hayes, J. E., Davidson, A. C., Kidd, J. R., Kidd, K. K., & Bartoshuk, L. M. (2010). Vegetable intake in college-aged adults is explained by oral sensory phenotypes and TAS2R38 genotype. *Chemosensation and Perception*, *3*, 137–148.

Dunn, M. A., Gomes, H., & Gravel, J. (2008). Mismatch negativity in children with autism and typical development. *Journal of Autism and Developmental Disorder*, *38*, 52–71.

Dunn, W., Griffith, J. W., Sabata, D., Morrison, M. T., MacDermid, J. C., Darragh, A., . . . Tanquary, J. (2015). Measuring change in somatosensation across the lifespan. *American Journal of Occupational Therapy*, *69*, 6903290020. doi:10.5014/ajot.2015.014845

Feeney, E., O'Brian, S., Scannell, A., Markey, A., & Gibney, E. R. (2011). Genetic variation in taste perception: Does it have a role in healthy eating? *Proceedings of the Nutrition Society*, *70*, 135–143.

Ferrè, E. R., Bottini, G., Iannetti, G. D., & Haggard, P. (2013). The balance of feelings: Vestibular modulation of bodily sensations. *Cortex*, *49*, 748–758.

Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., & Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. *Current Biology*, *22*, 814–819.

Frank, S. M., Baumann, O., Mattingley, J. B., & Greenlee, M. W. (2014). Vestibular and visual responses in human posterior insular cortex. *Journal of Neurophysiology*, *112*, 2481–2491.

Gagnon, I., Swaine, B., Friedman, D., & Forget, R. F. (2004). Children show decreased dynamic balance after mild traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *85*, 444–452.

Galle, S. A., Courchesne, V., Mottron, L., & Frasnelli, J. (2013). Olfaction in the autism spectrum. *Perception*, *42*, 341–355.

Getzmann, S., & Lewald, J. (2012). Cortical processing of change in sound location: Smooth motion versus discontinuous displacement. *Brain Research*, *1466*, 119–127.

Ghielmini, E., Poryazova, R., Baumann, C. R., & Bassetti, C. L. (2013). Sleepiness at the time of testing impairs olfactory performance. *European Neurology*, *69*, 58–64.

Gire, D. H., Restrepo, D., Sejnowski, T. J., Greer, C., De Carlos, J. A., & Lopez-Mascaraque, L. (2013). Temporal processing in the olfactory system: Can we see a smell? *Neuron*, *78*, 416–432.

Giuliani, F., & Schenk, F. (2015). Vision, spatial cognition and intellectual disability. *Research in Developmental Disabilities*, *37*, 202–208.

Gomes, H., Molholm, S., Ritter, W., Kurtzberg, D., Cowan, N., & Vaughan, H. J. (2000). Mismatch negativity in children and adults, and effects of an attended task. *Psychophysiology*, *37*, 807–816.

Grabherr, L., Nicoucar, K., Mast, F. W., & Merfeld, D. M. (2008). Vestibular thresholds for yaw rotation about an earth-vertical axis as a function of frequency. *Experimental Brain Research*, *186*, 677–681.

Greenberg, M. I., Curtis, J. A., & Vearrier, D. (2013). The perception of odor is not a surrogate marker for chemical exposure: A review of factors influencing human odor perception. *Clinical Toxicology*, *51*, 70–76.

Grothe, B., Pecka, M., & McAlpine, D. (2010). Mechanisms of sound localization in mammals. *Physiology Review*, *90*, 983–1012.

Hammill, D. D., Pearson, N. A., & Voress, J. K. (2013). *Developmental Test of Visual Perception, Third Edition (DTVP-3)*. San Antonio, TX: Pearson.

Han, J., Waddington, G., Adams, R., & Anson, J. (2013). Ability to discriminate movements at multiple joints around the body: Global or site specific. *Perceptual & Motor Skills: Perception*, *116*(1), 59–68.

Hayes, J. E., & Keast, R. S. J. (2011). Two decades of supertasting: Where do we stand? *Physiology and Behavior*, *104*, 1072–1074.

HealthMeasures. (2017). NIH Toolbox. Retrieved from http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox

Heilman, K. M., Voeller, K., & Alexander, A. W. (1996). Developmental dyslexia: A motor-articulatory feedback hypothesis. *Annals of Neurology*, *39*, 407–412.

Holmes, N. P., & Spence, C. (2004). The body schema and the multisensory representation(s) of peripersonal space. *Cognitive Process*, *5*, 94–105.

Hoover, K. C. (2010). Smell with inspiration: The evolutionary significance of olfaction. *Yearbook of Physical Anthropology*, *53*, 63–74.

Hoy, M., Egan, M., & Feder, K. (2011). A systematic review of interventions to improve handwriting. *Canadian Journal of Occupational Therapy*, *78*(1), 13–25. http://doi.org/10.2182/cjot.2011.78.1.3

Hummel, T., Kobal, G., Gudziol, H., & Mackay-Sim, A. (2007). Normative data for the "Sniffin' Sticks" including tests of odor identification, odor discrimination, and olfactory thresholds: An upgrade based on a group of more than 3,000 subjects. *European Archives of Otorhinolaryngology*, *264*, 237–243.

Jääskeläinen, I. P. (2010). The role of speech production system in audiovisual speech perception. *Open Neuroimaging Journal*, *8*, 30–36.

Jeannerod, M. (1981). Intersegmental coordination during reaching at natural visual objects. In J. Long & A. Baddeley (Eds.), *Attention and*

performance IX (pp. 153–168). Hillsdale, NJ: Erlbaum.
Jeannerod, M., & Biguer, B. (1982). Visuomotor mechanisms in reaching within extrapersonal space. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 387–409). Cambridge, MA: MIT Press.
Johnson, S. P. (2013). Development of the visual system. In J. Rubenstein and P. Rakic (Eds.), *Neural circuit development and function in the brain* (pp. 249–269). Waltham, MA: Academic Press.
Kaiser, M. L., Albaret, J. M., & Doudin, P. A. (2009). Relationship between visual-motor integration, eye-hand coordination, and quality of handwriting, *Journal of Occupational Therapy, Schools, & Early Intervention*, *2*(2), 87–95. doi:10.1080/19411240903146228
Kalagher, H., & Jones, S. S. (2011a). Developmental change in young children's use of haptic information in a visual task: The role of hand movements. *Journal of Experimental Child Psychology*, *108*, 293–307.
Kalagher, H., & Jones, S. S. (2011b). Young children's haptic exploratory procedures. *Journal of Experimental Child Psychology*, *110*, 592–602.
King, A. J., Dahmen, J. C., Keating, P., Leach, N. D., Nodal, F. R., & Bajo, V. M. (2011). Neural circuits underlying adaptation and learning in the perception of auditory space. *Neuroscience and Biobehavioral Reviews*, *35*, 2129–2139.
Lackner, J. R., & DiZio, P. A. (2000). Aspects of body self-calibration. *Trends in Cognitive Science*, *4*, 279–288.
Lopez, C., & Blanke, O. (2011). The thalamocortical vestibular system in animals and humans. *Brain Research Reviews*, *67*, 119–146.
Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates Inc.
Mailloux, Z., Mulligan, S., Roley, S. S., Blanche, E., Cermak, S., Coleman, G. G., . . . Lane, C. J. (2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy*, *65*(2), 143–151. doi:10.5014/ajot.2011.000752
Maravita, A., Spence, C., & Driver, J. (2003). Multisensory integration and the body schema: Close to hand and within reach. *Current Biology*, *13*(13), R531–R539.
Marr, D., Windsor, M. M., & Cermak, S. (2001). Handwriting readiness: Locatives and visuomotor skills in the kindergarten year. *Early Childhood Research & Practice*, *3*(1), 1–16.
Martin, N. A. (2006a). *Test of Visual Motor Skills* (3rd ed.). Novato, CA: Academic Therapy Publications.
Martin, N. A. (2006b). *Test of Visual Perceptual Skills* (3rd ed.). Novato, CA: Academic Therapy Publications.
Maslow, P., Frostig, M., Lefever, D. W., & Whittlesey, J. R. B. (1964). The Marianne Frostig developmental test of visual perception, 1963 standardization. *Perceptual and Motor Skills*, *19*, 463–499.
McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: Sensing and feeling. *Neuron*, *82*(4), 737–755.
Merfeld, D. M. (2011). Signal detection theory and vestibular thresholds: Basic theory and practical considerations. *Experimental Brain Research*, *210*, 389–405.
Merten, K., & Nieder, A. (2012). Active encoding of decisions about stimulus absence in primate prefrontal cortex neurons. *Proceedings of the National Academy of Sciences USA*, *109*, 6289–6294.
Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy*, *61*, 135–140.
Milner, A. D., & Goodale, M. A. (2008). Two visual systems re-visited. *Neuropsychologia*, *46*, 774–785.
Muaidi, Q. I., Nicholson, L. L., & Refshauge, K. M. (2009). Do elite athletes exhibit enhanced proprioceptive acuity, range and strength of knee rotation compared with non-athletes? *Scandinavian Journal of Medicine & Science in Sports*, *19*(1), 103–112.
Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy*, *52*, 819–828.
Murray-Slutsky, C., & Paris, B. A. (2014). Sensory discrimination disorders and intervention strategies. In C. Murray-Slutsky & B. A. Paris (Eds.), *Exploring the spectrum of autism: Autism interventions* (2nd ed.). Austin, TX: Hammill Institute on Disabilities.
Naseri, A. R., & Grant, P. R. (2012). Human discrimination of translational accelerations. *Experimental Brain Research*, *18*, 455–564.
Naudin, M., El-Hage, W., Gomes, M., Gaillard, P., Belzung, C., & Atanasova, B. (2012). State and trait olfactory markers of depression. *PLOS One*, *7*, 1–8.
Negri, R., Feola, M. D., Di Domenico, S., Scala, M. G., Artesi, G., Valente, S., . . . Greco, L. (2012). Taste perception and food choices. *Journal of Pediatric Gastroenterology and Nutrition*, *54*, 624–629.
Neveu, M. M., Jeffery, G., Moore, A. T., & Dakin, S. C. (2009). Deficits in local and global motion perception arising from abnormal eye movements. *Journal of Vision*, *9*(4), 1–15.
Okoye, R. (2005). Neuromotor prerequisites of functional vision. In M. Gentile (Ed.), *Functional visual behavior in children. An occupational*

therapy guide to evaluation and treatment options (2nd ed.). Bethesda, MD: AOTA Press.

Pleger, B., & Villringer, A. (2013). The human somatosensory system: From perception to decision making. *Progress in Neurobiology*, *103*, 76–97.

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2011). *Neuroscience* (5th ed.). Sunderland, MA: Sinauer Associates, Inc.

Reynolds, S., Kreider, C. M., & Bendixen, R. (2012). A mixed-methods investigation of sensory response patterns in Barth syndrome: A clinical phenotype? *American Journal of Medical Genetics Part A*, *158A*, 1647–1653.

Rine, R. M., Schubert, M. C., Whitney, S. L., Roberts, D., Redfern, M. S., Musolino, M. C., . . . Slotkin, J. (2013). Vestibular function assessment using the NIH toolbox. *Neurology*, *80*, S25–S31.

Rine, R. M., & Wiener-Vacher, S. (2013). Evaluation and treatment of vestibular dysfunction in children. *NeuroRehabilitation*, *31*, 507–518.

Romo, R., & de Lafuente, V. (2013). Conversion of sensory signals into perceptual decisions. *Progress in Neurobiology*, *103*, 41–75.

Schneck, C. (2010). Best practice in visual perception and academic skills to enhance participation. In G. F. Clark & B. E. Chandler (Eds.), *Best practices for occupational therapy in the schools*. Bethesda, MD: AOTA Press.

Schneider, P., Scherg, M., Dosch, H. G., Specht, H. J., Gutschalk, A., & Rupp, A. (2002). Morphology of Heschel's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nature Neuroscience*, *5*, 688–694.

Schwartz, S. H. (2010). *Visual perception. A clinical orientation* (4th ed.). New York, NY: McGraw Hill Medical.

Siegler, I., Viaud-Delmon, I., Israël, A., & Berthoz, A. (2000). Self-motion perception during a sequence of whole-body rotations in darkness. *Experimental Brain Research*, *134*(1), 66–73.

Slater, A., Morison, V., & Rose, D. (1983). Perception of shape by the new-born baby. *British Journal of Developmental Psychology*, *1*, 135–142.

Stiles, J., Akshoomoff, N., & Haist, F. (2013). Neural circuit development and function in the brain. In J. L. R. Rubenstein & P. Rakic (Eds.), *Comprehensive developmental neuroscience: Neural circuit development and function in the healthy and diseased brain* (pp. 271–296). Waltham, MA: Academic Press.

Stiles-Davis, J. (1988). Spatial dysfunctions in young children with right cerebral injury. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial cognition: Brain bases for development* (pp. 251–272). Hillsdale, NJ: Erlbaum.

Tong, J., Mao, O., & Goldreich, D. (2013). Two-point orientation discrimination versus the traditional two-point test for tactile spatial acuity assessment. *Frontiers in Human Neuroscience*, *7*, 1–11.

Turella, L., & Lingnau, A. (2014). Neural correlates of grasping. *Human Neuroscience*, *8*, 1–11. doi:10.3389/fnhum.2014.00686

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematical skills. *Child Development*, *85*(3), 1162–1076. doi:ezproxy.newcastle.edu.au/10.1111/cdev.12165

Vidyasagar, T. R., & Pammer, K. (2010). Dyslexia: A deficit in visuospatial attention, not in phonological processing. *Trends in Cognitive Science*, *14*, 57–63.

Wandell, B. A. (2011). The neurobiological basis of seeing words. *Annals of the New York Academy of Science*, *1224*(1), 63–80.

Wandell, B. A., Rauschecker, A. M., & Yeatman, J. D. (2012). Learning to see words. *Annual Review of Psychology*, *63*, 31–53. doi:10.1146/annurev-psych-120710-100434

Wepman, J. M., & Reynolds, W. M. (1986). *Wepman's Auditory Discrimination Test-2nd Edition (ADT™)*. Los Angeles, CA: Psychological Services.

Westcott, S. L., Crowe, T. K., Deitz, J. C., & Richardson, P. K. (1994). Test-retest reliability of the Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB). *Physical and Occupational Therapy in Pediatrics*, *14*, 1–22.

Yackinous, C. A., & Guinard, J. X. (2002). Relation between PROP (6-n-propylthiouracil) taster status, taste anatomy and dietary intake measures for young men and women. *Appetite*, *38*, 201–209.

Znamenskiy, P., & Zador, A. M. (2013). Corticostriatal neurons in auditory cortex drive decisions during auditory discrimination. *Nature*, *497*, 482–485.

PART

III

Tools for Assessment

CHAPTER

8

Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests

Shelley Mulligan, PhD, OTR/L, FAOTA

The Sensory Integration and Praxis Tests (SIPT) help us to understand why some children have difficulty learning or behaving as we expected . . . they . . . evaluate some important abilities needed to get along in the world.

—A. Jean Ayres

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe the utility of the Sensory Integration and Praxis Tests (SIPT) for clinical practice.
- ✔ Explain the findings of factor and cluster analyses completed on the SIPT and how this information supports the assessment process.
- ✔ Define the role of the SIPT as part of a comprehensive assessment for children with suspected sensory integrative difficulties.

Purpose and Scope

The Sensory Integration and Praxis Tests (SIPT) are designed primarily to examine aspects of sensory discrimination and praxis. They are intended to be used as part of an overall evaluation process for school-aged children who experience difficulties in these areas that impact occupational performance and participation. This chapter offers a brief introduction to this test battery and guides readers to understand the various factor and cluster analyses that form the foundation for identifying sensory integrative strengths and weaknesses in children. A great deal more detail on the SIPT can be found in the test manual (Ayres, 2005), and that information is not repeated in this chapter. Because it is crucial that the SIPT not be used in isolation, discussion is included here regarding integration of this tool with other assessments and observations that complete the picture. We present an analysis model that has been used in certification courses as a way to organize the assessment process. To illustrate this assessment process, a case study is presented.

Description and Purpose of the Sensory Integration and Praxis Tests

Standardized assessment tools specifically designed to evaluate sensory processing and integration are important for identifying whether sensory processing problems are present and interfering with a child's occupational performance. Such tools provide objective data for determining the types or patterns of sensory integration (SI) dysfunction that exist as well as the extent or severity of the dysfunction. This information is integral for guiding the intervention planning process, and it is helpful for justifying the need for occupational therapy services using an SI approach. Such standardized testing may also be used to evaluate the effectiveness of intervention programs designed to improve SI functions in children.

The most psychometrically sound, standardized, performance-based assessment tool available to measure SI functions is the SIPT (Ayres, 2005). Therefore, this section of the chapter is devoted to content describing the SIPT and how the test is used in the context of comprehensive occupational therapy evaluations of children following an SI approach.

The SIPT is comprised of 17 tests, is norm-referenced, and was designed for children from 4 years 0 months of age to 8 years 11 months of age who are suspected of having a sensory integrative disorder. Each of the tests is individually administered, and the entire battery takes approximately 1.5 to 2 hours to administer. Completion of advanced training through the Comprehensive Training and Certification Program offered by Western Psychological Services/University of Southern California (see http://chan.usc.edu/academics/usc-wps-certification) has been expected for therapists wishing to learn and use the SIPT. The SI functions measured by the SIPT can be categorized into four overlapping areas:

1. Visual form and space perception
2. Tactile discrimination
3. Praxis (various forms)
4. Vestibular and proprioceptive processing

A brief description of each test by group is shown in Table 8-1. In consideration of the model of SI dysfunction presented in Figure 1-6, it is important to recognize the facets of the model that are and are not addressed by the SIPT. Indicators of poor SI and praxis are well captured by the SIPT including some aspects of postural-ocular control, visual-motor control, and, to a lesser extent, body percept or kinesthesia. These deficits may result in either (or both) of two common patterns of dysfunction: Vestibular-Bilateral Integration and Sequencing (VBIS) disorder, and Somatopraxis, which is dyspraxia with an underlying somatosensory basis. Processing and sensory discrimination functions related to the visual, tactile, proprioceptive, and vestibular systems are addressed by the SIPT, although the test does not address the processing of auditory, olfactory, and gustatory sensory input. Sensory modulation including sensory responsivity is also not directly measured by the SIPT. It is, however, important to note that clinical observations made during the administration of the SIPT are very useful for capturing aspects of sensory modulation, as well as for identifying some functional or occupational performance challenges and behavioral consequences of sensory processing deficiencies that might exist.

The SIPT provides z-scores for each of the 17 tests, and scores falling within 1 standard deviation from the mean are interpreted as being within the normal range (Ayres, 2005). Each of the 17 tests was shown to discriminate between children with SI problems and those without, using 1 standard deviation below the mean as the criteria for performance that would be considered below average (Ayres, 2005). The SIPT was normed using approximately 2,000 North American children who were representative at the time of U.S. population characteristics and distribution in terms of race, gender, and geographic location, as well as urban and rural representation. There are separate norms for boys and girls, and there are 12 age groups. Children 4 to 5 years of age are divided by 4-month intervals, whereas children 6 through 8 years of age are divided by 6-month intervals.

In addition to using the SIPT z-scores from each of the tests to interpret a child's SI performance and dysfunction, a number of other data sources are available and should be used to assist in the interpretation process. The SIPT is a well-researched tool, and many multivariate factor analytic studies and cluster analyses have been completed with its tests (Davies & Tucker, 2010). These studies have contributed to the establishment of construct validity of the SIPT (discussed in more detail next) and are useful in the interpretation process for identifying specific patterns of SI dysfunction seen in individual children. The test manual (Ayres, 2005) describes many of the factor analyses that were

TABLE 8-1 Functions Measured by SIPT

PRIMARY DOMAIN	TEST	DESCRIPTION
Visual Form and Space, Visual-Motor Coordination; Visuopraxis	Space Visualization (SV)	Motor-free visual form and motor coordination; mental manipulation of objects
	Figure Ground (FG)	Perception and location of figures on a rival background
	Design Copying (DC)	Copying simple and complex two-dimensional designs; approach for copying
	Constructional Praxis (CPr)	Block construction; ability to relate objects to one another in three-dimensional space
	Motor Accuracy (MA)	Eye-hand coordination, tracing, motor control
Tactile Perception and Discrimination	Finger Identification (FI)	Discrimination of touch to individual fingers
	Localization of Tactile Stimuli (LTS)	Perception of location of tactile stimuli applied to the forearm and hand
	Graphesthesia (GRA)	Perception and replication of designs drawn on the back of the hands
	Manual Form Perception (MFP)	Stereognosis; matching a shape held in one hand with a visual counterpart or with another shape felt by the other hand
Praxis	Bilateral Motor Coordination (BMC)	Sequencing and moving both hands and both feet in smooth patterns
	Sequencing Praxis (SPr)	Imitating motor sequences of hands and fingers
	Postural Praxis (PPr)	Imitating, planning, and executing static body postures
	Oral Praxis (OPr)	Imitating, planning, and executing oral motor movements of the lip, tongue, and jaw
	Praxis on Verbal Command (PrVC)	Planning and executing static body postures from verbal directions
Vestibular and Proprioceptive Processing	Kinesthesia (KIN)	Perception of passive hand and arm movements
	Standing and Walking Balance (SWB)	Static and dynamic balance on one or both feet, with eyes open and closed
	Post-Rotary Nystagmus (PRN)	Duration of the vestibular-ocular reflex following rotation

done during the development of SIPT as well as much later (Mulligan, 1998); the manual also details how this research can be used to assist in the interpretation process. The SIPT report also generates a statistic called a *D-squared index value* that indicates how closely the child's scores fit each of six cluster groupings. The cluster groupings represent patterns of SI functioning that were found during the development of the test. Therefore, interpreting SIPT scores is a complex process using multiple data sources from the test itself as well as considering other sources of evaluation data, such as information from occupation-based assessments, parent interviews, and clinical observations. Further information on how SIPT data is synthesized with other data sources to complete comprehensive evaluations of children is provided later in this chapter, following a review of the validity and reliability of the SIPT. It is also touched on in Chapter 11 (Interpreting and Explaining Evaluation Data), relative to the interpretation of evaluation findings.

HERE'S THE POINT

- Aside from the SIPT (Ayres, 1989, 2005), there are few objective standardized assessment tools for measuring SI functions in children.
- The SIPT is especially useful for identifying deficits with visual form and space perception, tactile discrimination and praxis, and for identifying specific patterns of SI dysfunction.

- Administration of the SIPT, in conjunction with data gathered from caregiver interviews, informal and structured clinical observations, and inventories or questionnaires for quantifying behaviors associated with sensory processing and modulation, provide comprehensive evaluations of sensory processing and integration.

Validity and Reliability of the Sensory Integration and Praxis Tests

Validity

Validity is the ability to draw meaningful inferences from test scores for an intended purpose, and it reflects the extent to which a test measures the construct(s) it intends to measure. SI functioning is a complex, multidimensional construct that can be inferred only by behaviors that can be observed, which makes validity evidence for the SIPT especially important. The test manual (Ayres, 2005) provides an abundance of research supporting the tests' validity, which will be summarized only briefly here.

The SIPT evolved through decades, and it was the result of a revision of an earlier, 12-subtest version of the test battery, titled the Southern California Sensory Integration Test (SCSIT; Ayres, 1972). Content included in the SIPT was based on a review of test items by experts in the field, with consideration of literature supporting the neurological basis for SI processes, as well as by data-driven methods, such as factor and cluster analyses. Whereas factor analyses group *tests* together, cluster analyses group *individuals* with similar patterns of scores. Factor analyses conducted from the mid-1960s through 2011 used subsets of the tests as well as the entire battery (both the SIPT and its earlier version); results revealed several fairly consistent factors representing patterns of SI dysfunction. These patterns have included:

- Somatodyspraxia, a pattern with low performance on measures of tactile and proprioceptive functions and low praxis or motor planning scores (Ayres, 1969, 1977, 1989; Mailloux et al., 2011)
- Visual form and space pattern with low scores on visual perceptual, visual-motor, and visual construction tasks (Ayres, 1969, 1972, 1977, 1989; Mailloux et al., 2011; Mulligan, 1998)
- Sensory modulation deficits include under- and over-responsivity to sensory stimuli and fluctuating responses. These responses are often also seen with challenges regulating behavior. The challenges are reflected in behaviors such as hyperactivity, sensory craving or seeking, avoidance behaviors, and distractibility. (Ayres, 1969, 1972, 1977; Mailloux et al., 2011)
- Vestibular processing, with postural-ocular problems, and bilateral integration and sequencing (BIS) deficits (Ayres 1969, 1972, 1977, 1989; Mailloux et al., 2011; Mulligan, 1998)

Three studies using factor analysis conducted during the development of the SIPT are described in detail in the SIPT manual (Ayres, 1989, 2005). One study used a sample of children who were developing typically, one used a sample of children with learning or sensory integrative dysfunction, and the third study used a combined sample of children with and without learning or SI dysfunction. Scores from the children who were developing typically suggested four factors—somatopraxis, visuopraxis, vestibular processing, and somatosensory processing—and a kinesthetic-motor factor. When SIPT scores from a sample of children with learning and SI disorders were considered, five factors emerged, including somatopraxis, somatosensory, and visuopraxis, as was seen with the normative sample. In addition, a pattern of BIS emerged, along with a pattern of Praxis on Verbal Command (very low scores on the Praxis on Verbal Command test with moderately high scores for Post-Rotary Nystagmus). Mulligan (1998) conducted factor analyses on a sample of more than 10,000 children tested with SIPT. She found similar patterns of SI dysfunction, including BIS deficits, somatosensory processing problems, visual perception issues, and dyspraxia. In addition, Mulligan's results showed that the four patterns of dysfunction were highly correlated, suggesting an underlying encompassing disorder, perhaps representing sensory integrative disorder. Most recently, Mailloux and colleagues (2011) conducted a factor analysis with a clinical sample of 425 children using SIPT scores as well as a measure of sensory modulation, including attention and tactile defensiveness. The four factors or patterns emerging from this study were quite consistent with the findings of previous studies, and they included the following patterns: Dyspraxia; Vestibular/Proprioceptive Bilateral Integration and Sequencing; Tactile and Visual Discrimination; and Tactile Defensiveness and Inattention. The research studies conducted on patterns of sensory integrative function and dysfunction provide solid evidence that SI processes are multidimensional and that the SIPT is a useful tool for uncovering specific patterns of dysfunction.

Another multivariate statistical technique that has been used to support the construct validity of the SIPT is cluster analysis. Using a combined sample of about 300 children with and without learning and SI deficits, data from SIPT scores generated a total of six cluster groupings (Ayres, 2005). Ayres interpreted two of the clusters as representing normal functioning: High-Average Sensory Integration and Praxis, and Low-Average Sensory Integration and Praxis. One cluster grouping characterized by very low scores on the Praxis on Verbal Command test, and moderately high scores on Post-Rotary Nystagmus, was interpreted as representing a problem other than an SI deficit (Praxis on Verbal Command). This pattern was hypothesized by Ayres (2005) to be associated with deficiencies with attention, learning, and auditory processing. The other three cluster groupings were interpreted as being associated with patterns of SI dysfunction. Low Average BIS was the most common cluster grouping, and it was characterized by children with the lowest scores on tests identified with a BIS component and with typical scores on the rest of the SIPT. The Generalized Sensory Integrative Dysfunction cluster included children with very low scores on almost all 17 tests, and, finally, the Visuo- and Somatodyspraxia cluster included children with below-average scores primarily on measures of tactile processing, praxis, and tests of form and space perception. Mulligan (2000) also conducted a cluster analysis with a larger data set, and she found similar diagnostic patterns, including:

- BIS
- Generalized Sensory Integration and Dyspraxia-Severe
- Generalized Sensory Integration and Dyspraxia-Moderate
- Dyspraxia
- Average Sensory Integration and Praxis

The research using cluster analyses assists in the interpretation of SIPT scores of children and the level of severity of dysfunction when it occurs. Furthermore, cluster analyses have supported much of the data obtained by the factor analytic studies regarding subtypes of SI disorder, the underlying sensory basis of disorders such as praxis, and relations among facets of sensory processing.

Other forms of validity evidence were also obtained during the development of SIPT, and the evidence has been augmented during the past 25 years (Mulligan, 2011). Ayres demonstrated that the SIPT has discriminate validity such that children with known disabilities score more poorly on the SIPT than do children who are developing typically (Ayres, 2005). Subsequently, studies have shown the kind of SI dysfunction associated with specific disabilities or populations, such as autism (Ben-Sasson et al., 2008; Roley et al., 2015) and attention disorders (Mulligan, 1996; Parush, Sohmer, Steinberg, & Kaitz, 1997). Murray, Cermak, and O'Brien (1990) found children with learning disabilities scored significantly lower on four out of six tests measuring form and space perception as well as tests of visual construction, also supporting the idea that there is a relation among visual perception, motor coordination, and praxis functions. Developmental trends have been shown by the test such that older children demonstrate more skilled performance than do younger children, supporting the idea of SI functioning as a developmental construct.

A limited amount of data regarding criterion-related validity is available. For example, correlations of SIPT scores with Kaufman-ABC scores supported the aspects of the SIPT for measuring sequential processes, as the SIPT items correlated highly with the K-ABC items known to measure sequential processing (Ayres, 2005). Cermak and Murray (1991) found moderately high correlations between the constructional praxis tests of the SIPT (Design Copying [DC] and Constructional Praxis [CPr]) and other tests known to assess similar aspects of constructional praxis, the Beery-Buktenica Developmental

Tests of Visual Motor Integration, and the Block Design of the Wechsler Intelligence Scale for Children. Predictive criterion-related validity was addressed by Parham (1998) who demonstrated that sensory integrative functioning as measured by the SIPT was able to predict later academic achievement in school-aged children.

Reliability

Evidence of the **reliability** of the SIPT is presented in the manual (Ayres, 1989, 2005). Stability across trained administrators is very strong, with correlation coefficients of inter-rater reliability ranging from 0.94 to 0.99. The stability of the SIPT through time is also acceptable, with especially high test-retest reliability for the tests of praxis with coefficients ranging from 0.70 to 0.93 for a combined sample of children developing typically and children with known learning or SI problems (Ayres, 2005). Four of the tests (Kinesthesia, Figure Ground, Localization of Tactile Stimuli, and Post-Rotary Nystagmus) demonstrated relatively low stability through time, with reliability coefficients ranging from 0.48 to 0.56.

HERE'S THE EVIDENCE

It is important that professionals who use standardized assessment tools in their practice are aware of ongoing research that is being done on the tools that they routinely use and how such research might impact how those professionals might apply these tools in their practice. For example, Mailloux and colleagues (2011) examined the construct validity of the SIPT in their study titled, "Verification and Clarification of Patterns of Sensory Integration Dysfunction." In this study, evaluation data (SIPT scores, along with two variables related to sensory modulation-measure of attention, a tactile defensiveness score) were analyzed using a clinical sample of 273 children. The results supported four main factors: (1) Dyspraxia; (2) Vestibular/Proprioceptive Bilateral Integration and Sequencing; (3) Tactile and Visual Discrimination; and (4) Tactile Defensiveness and Inattention. These patterns support earlier factor analyses done by Mulligan (1998) and Ayres (1989), which strengthens our confidence in the clinical application of these patterns of SI dysfunction. In addition, for the first time, two SIPT subtests that were always thought to fit theoretically within a pattern of vestibular-proprioceptive processing, Post-Rotary Nystagmus and Kinesthesia, did load on the Vestibular/Proprioceptive Bilateral Integration and Sequencing as would be expected.

Analyses of SIPT Scores with Other Assessment Data for Completing Comprehensive Evaluations of Children

The SIPT's contribution to a comprehensive evaluation of children identified with, or suspected of having, SI disorders is in providing a standardized, rigorous, objective measure of many forms of praxis, tactile discrimination, nonmotor visual perception including form and space perception, aspects of vestibular and proprioceptive functioning, visual-motor skills, and bilateral motor coordination. The combination of the 17 tests of the SIPT has been well-researched so that they also yield useful information regarding specific patterns of SI dysfunction, most notably somatopraxis, visuo-praxis, BIS disorder, and postural-motor disorder, as well as a more generalized sensory integrative disorder. Throughout this section of the book, it has been emphasized that comprehensive occupational therapy evaluations of children using an SI approach consider not only the underlying body function deficits that the SIPT is designed to measure but also the way that deficits that are discovered impact a child's ability to perform his or her desired and required daily occupations.

The evaluation process, therefore, begins by gathering information about a child's concerns, occupational and medical history, strengths, and priorities, and this is usually accomplished through conducting interviews with the caregiver, teacher, and child. Assessment of the child's occupational performance in context of the many roles the child assumes in his or her daily life (e.g., social partner and player, student, worker) and during the completion of necessary self-care tasks, such as eating, bathing, and toileting, should be completed before SIPT administration. Also, occupational performance is often evaluated through interviews using standardized evaluations of occupational performance, such as the Assessment of Motor and Process Skills (Fisher, 2003) or the Canadian Occupational Performance Measure (Law et al., 2005). Therapists also should conduct observations of children in the context of their daily activities in the home, during play, or at school. Early in the evaluation process, therapists begin to hypothesize how potential SI deficits might be influencing occupational performance, and this theorizing often results in a strong rationale for further testing with the SIPT.

In the next phase of the evaluation process, limitations of the SIPT as a measure of processing and integration of sensory information by the central nervous system should be considered so that appropriate additional evaluation activities are included. For instance, assessment of sensory modulation should be considered as the SIPT does not include formal measures of modulation. This can be completed through the administration of standardized caregiver questionnaires, such as the Sensory Profile-2 (Dunn, 2014) or the Sensory Processing Measure (SPM)-Home form (Parham & Ecker, 2007). Modulation also can be examined by doing interviews with relevant people regarding the children's sensory history as well as their usual responses to types of sensory stimuli in the contexts of daily routines and activities. Common types of sensory modulation disorders that have been identified in the literature include sensory over-responsivity (e.g., tactile and auditory defensiveness, gravitational insecurity) or under-responsivity, which may be reflected in poor sensory registration. Clinical observations and procedures to evaluate vestibular, proprioceptive, and postural-ocular functions should also be administered, as test items measuring these aspects of SI and processing on the SIPT are limited (see Chapter 9, Using Clinical Observations within the Evaluation Process, for more information on clinical observations). Finally, when diagnostic judgments are being made, consideration of other explanations for atypical behavior or occupational performance problems (other than sensory integrative deficits) often need to be considered and explored further. This might include cognitive functioning, emotional and mental health concerns, and orthopedic concerns, as well as any sociocultural or environmental factors that might be influencing the child's functioning. It is often just as important in an evaluation to rule out the presence of a sensory integrative disorder as it is to discover a disorder exists. Finally, depending on the referring concerns, additional assessments might be warranted to gather more detailed information on specific functions, such as fine and gross motor skills, handwriting performance, or social skills.

Synthesis of Evaluation Data

Once all the necessary evaluation information has been gathered, the next step in the evaluation process is to organize and synthesize all the information so that a determination can be made regarding the nature of any SI problems that are uncovered as well as how they are impacting the child's occupational performance. Occupational therapists engage in a process of clinical reasoning (or, more simply put, therapists' thinking) to examine, organize, synthesize, and interpret all the data that has been collected. An interpretation worksheet was created by the authors of the Comprehensive Training and Certification Program in Sensory Integration, Course 3 for this purpose, and it is presented in Figure 8-1 (Roley, 2012). This worksheet considers data gathered from the SIPT, as well as other related clinical observations and data sources.

The top section of the worksheet leads the therapist to consider basic processing within sensory systems first. The processing of information by the visual, vestibular, and somatosensory (tactile and proprioceptive) systems is emphasized, along with the modulation of sensory information from all sensory domains, with consideration given to the multiple types of modulation disorders. Within these sections on the worksheet, the therapist has an opportunity to record and analyze scores from the individual tests of the SIPT with relevant observational or other data reflecting performance within that sensory domain or pattern of dysfunction. It is important to note that the specific SIPT tests included within each section were placed strategically and thoughtfully to represent the relationships among the tests that have been validated through the many previous studies using factor and cluster analyses discussed in the previous section. Moreover, the tests are listed in order of importance for defining a problem in that area, as determined by the number of studies that identified the relationship as well as the size of factor loading values derived by the research.

Visual	Score	Vestibular	Score	Somatosensory	Score	Interoception/ Sensory Modulation	Score
Visual Spatial SV FG **Visual Praxis** DC CPR MAC **Haptic Form and Space** MFP GRA Observations		**Postural Control** SWB Prone extension Stability Righting Equilibrium **Vestibular-Ocular** Low PRN Ocular stability Head/neck/eye coordination Observations		**Proprioception** KIN SWB Poor body scheme Observations, e.g., finger/nose, thumb/finger touching, diadokokinesis **Tactile** LTS GRA FI MFP Observations		**Sensory responses** Over/Under Fluctuating **SPM results** Visual Hearing Touch (LTS) Body awareness Balance and motion **SP results** Hypersensitive Sensory avoiding Hypo-response Sensory seeking Observations Arousal Affect Activity level Attention	
		Bilateral Integration	Score	**Praxis**	Score		
		BMC SPr OPr GRA MFPII MAC Observations (e.g., skipping, jump jacks)		PPr OPr PRVC (SPr) (BMC) Flexion Observations (e.g., play)			
Right Hemisphere IQ	Score	**Laterality**	Score	**Praxis on Verbal Command**	Score	**Left Hemisphere IQ**	Score
Low performance High verbal Poor visual spatial SV, FG, FI, DC Significantly lower left-sided scores Low frustration toler.		SVCU PHU R/L differences Poor scores on directionality, reversals, inversions, jogs Observations		PRVC (LOW) PRN (average to high) Poor sequencing Possible low scores on: OPr, SPr, BMC, SWB, DC		High performance Low verbal Poor sequencing	
Irregular Neurological Signs *circle if present:* hyper- or hypotonia, associated movements, clonus, increased PRN, tremors, tics, choreoathetosis, hypersensitivity to movement, seizures, other *specify*…							

FIGURE 8-1 Sensory Integration and Praxis Test (SIPT) analysis worksheet. SPM: Sensory Processing Measure; SP: Sensory Profile; SVCU: Space Visualization Crossing Midline; PHU: prefered hand use; R/L: right/left; IQ: intelligence quotient.

The middle section in Figure 8-1, including BIS and Praxis, is placed as such, based on the assumption that these patterns of SI dysfunction are largely the result of underlying deficits with vestibular, proprioceptive, or tactile processing. During the clinical reasoning process, the therapist considers the contributions of basic sensory system functioning to problems associated with BIS or dyspraxia. The potential relations between problems with BIS and dyspraxia (and vice versa) are also considered, as well as how such problems relate to the child's motor and other skills.

The bottom section of the worksheet suggests that some problems that appear as though they are deficits with sensory processing and integration may instead be linked with a higher level, cortical problem rather than be the result of a sensory processing problem. Information may be obtained that suggests a right or left hemisphere deficit, learning or cognitive impairment, or a neuro-motor deficit, such as seizures or cerebral palsy. These potential factors assist in differential diagnoses, and those factors are important for understanding how such neurological irregularities might co-exist with, affect, or rule out a deficit in sensory modulation or processing.

Using the worksheet is effective for applying the abundance of research on the patterns of SI dysfunction and for organizing and interpreting SIPT scores. The child's D-squared index values for each of the SIPT's six cluster groupings are also data that can be used to assist in clarifying whether a child has an SI problem and, if so, the nature of the dysfunction. When a child is identified as fitting within a particular cluster grouping, the common characteristics of children from the matching cluster grouping can be applied to assist in describing that child's SI deficits.

The final step in the evaluation process is to consider how a child's SI problems based on standardized testing with the SIPT contribute to the child's challenges with occupational performance and other skill deficits. Such careful thought assists in developing strategies to reduce the impact of a child's SI dysfunction on his or her daily life, and it provides direction for the development of effective intervention for remediating the SI deficits that are impacting the child's occupational performance.

HERE'S THE POINT

- The synthesis of data from multiple sources, including the SIPT, is a complex process, and tools such as the interpretation worksheet provided in this chapter are useful for helping therapists organize and analyze their evaluation data.
- It is vital that therapists are aware of the strengths and weaknesses of the standardized measures that they are using. Therapists must administer and interpret scores from those tools in ways that are consistent with the research that has been done and with the authors' recommendations for how the test is intended to be used.

PRACTICE WISDOM

We are recommending that you use multiple data sources for your evaluations. However, sometimes you will be faced with a dilemma when data that you obtain from two (or more) different sources about the same function reveal different results. For example, what should you do if your clinical observations lead you to hypothesize that a child's kinesthetic awareness is poor, but the score on the Kinesthesia test of the SIPT fell within the average range? To resolve such dilemmas, use your clinical judgment; consider the standard error of measure of the test that you administered and how confident you are the child performed the test or the behaviors that were observed to his or her true ability. Considering these and other contextual factors and knowledge about how the child typically performs will help you to resolve conflicting assessment data when this happens.

CASE STUDY ■ USING THE SIPT IN THE EVALUATION PROCESS: LILLY

Lilly was a 5-year-old girl who was evaluated by an occupational therapist at a private clinic specializing in working with children with SI and processing disorders and their families. Her mother was concerned that Lilly's fine and gross motor skills were below average and that she had trouble getting along with peers. Her mother also reported that Lilly had a lot of anxiety, that she was a very picky eater, and that she was very sensitive to sensory stimuli such as loud noises. In order to get a full picture of Lilly's strengths and needs, the therapist planned her evaluation as follows: an unstructured parent interview with Lilly's mother; completion of the SPM-Home form by her mother; clinical observations of Lilly's sensory and motor functions, fine and gross motor skills, and play behaviors; and administration of the SIPT (Ayres, 2005).

Information gathered from the parent interview revealed Lilly is an only child who lives with her parents in a rural neighborhood. Early developmental motor milestones were achieved within the age-appropriate ranges; Lilly walked by 13 months of age and said her first words before 14 months. Despite an unremarkable medical history, Lilly was described by her mother as an emotionally sensitive child who frustrates easily and who has trouble following through with simple requests at home. She actively participates but requires some assistance with most aspects of her self-care, such as grooming, bathing, and dressing, and there were very few foods that she would eat. Her mother reported that activities outside the home are limited because Lilly becomes overstimulated easily, especially when there is a lot of noise, or if there are other people around. Her mother said that she is doing average school work with reading and math for a child of her age, although her pencil skills are poor. Lilly prefers sedentary play such as playing with dolls, and although she interacts quite well with adults, she tends to be very withdrawn and more of an observer when with children her own age. She does not enjoy playing on playground equipment and cannot pump a swing. Lilly wants to learn to ride her two-wheeled bike with training wheels, but, thus far, she had been too fearful to get on it.

Lilly's scores on the SPM-Home form based on her mother's ratings of behaviors believed to reflect sensory processing abilities are reported in Table 8-2.

Lilly's scores on the SPM suggest that she processes information from her sensory

TABLE 8-2 Lilly's Scores from the Sensory Processing Measure

SENSORY AREA	*T-SCORE (MEAN = 50, SD = 10)	INTERPRETATION
Social Participation	67	Some Differences
Visual	71	Dysfunction
Hearing	76	Dysfunction
Touch	74	Dysfunction
Body Awareness	74	Dysfunction
Balance and Motion	75	Dysfunction
Planning and Ideas	63	Some Differences

*Higher scores represent more dysfunction.

systems in many atypical ways. With respect to her visual system, Lilly is sensitive to light, and often she lacks awareness of objects or activity in her environment. She focuses adequately using her vision and discriminates between objects, such as puzzle pieces, without difficulty. With respect to auditory processing, Lilly often needs directions to be repeated, and often it requires more effort than would be typical to get her attention; however, she is overly sensitive to loud noises. In the tactile area, her mom reported that she is overly sensitive to touch during grooming and dressing activities. Her play is somewhat rigid, and she lacks creativity, suggesting some motor planning problems. Her score on the social participation scale indicated some challenges, noted more with her peers than when interacting with adults. Overall, Lilly has a tendency to be overly sensitive to auditory and tactile sensory input, and she can become overwhelmed easily in environments that provide a great deal of sensory stimuli. Difficulties with processing proprioceptive and vestibular sensory information were also noted, which may be impacting her body awareness, comfort with movement activities, balance, and motor coordination.

Observations of gross motor skills indicated that Lilly moves about her environment without difficulty and is able to easily run and walk. She was able to walk upstairs through alternating her feet without the use of the railing (although she preferred to hold the railing), and when descending the stairs, she placed both feet on each step. She was able to gallop but not skip, and she was able to jump by clearing both feet from the floor at the same time. Ball play, including consistency with catching as well as accuracy of tossing and kicking, was below average. She was nervous when asked to lie prone over the therapy ball, to sit and bounce on the therapy ball, and when sitting on the platform swing even when supported by the therapist. Lilly's muscle tone was assessed to be within the average range. Her gross motor movements were often poorly graded. She was able to stand on one foot for 5 seconds and hop on one foot for three consecutive times, but she had difficulty coordinating both sides of her body during attempts to skip and do jumping jacks. In the fine motor area, Lilly was able to put together Lego® blocks as well as a simple 12-piece wooden puzzle with pieces that set into a board. She enjoyed drawing on the white board, and she was able to hold the marker using an immature finger grasp. She was able to print her first name but not her last name.

Other observations revealed that Lilly was friendly and able to warm up easily with an unfamiliar adult. She tended to give up very quickly when challenged by a task and often would refuse politely even to try a task. She was quick to notice subtle background noises, and she was uncomfortable with movement that challenged her balance or when her feet were raised from the floor, such as when sitting on the platform swing and the therapy ball.

Results from the 17 individual tests of the SIPT generated the z-scores presented in Table 8-3.

Visual form and space perception were a relative strength for Lilly, although, when combined with motor demands such as when copying designs or doing construction tasks, she experienced difficulty. Lilly performed poorly on most tests of praxis, suggesting dyspraxia resulting from underlying problems with somatosensory and vestibular processing. Lilly's pattern of SIPT scores resulted in a D-squared index value (.58) that likened her to the visuo-somatodyspraxia cluster grouping. Children such as Lilly who fall within that cluster grouping tend to present with significant SI dysfunction in the areas of somatosensory

TABLE 8-3 SIPT Z-Scores for Lilly

Space Visualization: –0.8	Figure–Ground: –0.2
Manual Form Perception: 0.4	Kinesthesia: –1.5
Finger Identification: –0.6	Graphesthesia –0.9
Localization of Tactile Stim. –0.6	Praxis on Verbal Command: –1.4
Design Copying: –1.9	Constructional Praxis: –1.6
Postural Praxis: –2.0	Oral Praxis –1.6
Sequencing Praxis: –2.0	Bilateral Motor Coordination: –0.7
Standing & Walking Balance: –1.4	Motor Accuracy: –0.3
Post-Rotary Nystagmus: –0.5	

and vestibular processing as well as dyspraxia, with some visual-spatial challenges.

The interpretation worksheet was completed for Lilly to assist in interpreting and synthesizing all the assessment data that was gathered, and it is presented in Table 8-4. As illustrated, Lilly exhibits more than one area or pattern of SI dysfunction. Most notably, she has a sensory modulation disorder, with over-responsivity being the main subtype, and dyspraxia, a sensory-based motor disorder that appears to be related to underlying challenges in processing somatosensory and vestibular sensory information. It is hypothesized that these sensory processing disorders are contributing to her challenges in developing fine and gross motor skills as well as in her ability to demonstrate age-appropriate social play behaviors. These deficits also impact her comfort level and ability to perform in typical, day-to-day situations that inherently involve a great deal of sensory input such as going to the mall or playground, as well as completing many self-care tasks. Situations that require her to be flexible or adapt to change, learn new skills or problem-solve to meet the demands of novel situations when playing with peers, or complete a self-care task such as taking a shower are also challenging.

It is important to acknowledge that Lilly has many strengths. As noted previously, when interacting with adults, she is comfortable, friendly, and eager to please. She moves about her environment adequately, and she has developed many motor, academic, and self-help skills typical of children her age. She would be an excellent candidate to receive occupational therapy using an SI approach.

Lilly would benefit from intervention to address the SI deficits that are impacting her development of social-emotional skills, play behaviors, self-help, and motor skills. Intervention recommendations included two 1-hour occupational therapy sessions for 3 to 4 months using the Ayres' Sensory Integration (ASI) approach, combined with some specific skills training for developing her pencil skills and ability to ride her bike. Sensory-based activities were implemented to promote social skills and motor planning, to reduce tactile hypersensitivities, especially to help expand the repertoire of what she is willing to eat, and to increase her comfort level with grooming and dressing tasks. Intervention also included parent and child education about sensory integrative disorders along with problem-solving strategies and solutions to minimize the negative impact that her sensory differences were having in the context of her daily life activities at home and in the community. Intervention strategies are discussed in more detail in later chapters; however, some other suggestions to address her sensory integrative concerns and maximize her ability to perform her desired occupations might include the following:

- During tabletop activities, such as puzzles, looking at books, drawing, or prewriting, minimize distractions, such as noise, and provide occasional verbal cues for encouragement and to help her keep focused.
- Engage in prewriting activities and simple craft activities and play with construction toys and dolls (including accessories such as clothing) to build visual motor skills, motor planning, and dexterity.
- Play activities that are very physical in nature, including the use of playground equipment, ball play, riding a bike, and running and jumping games, would be good for Lilly. Presenting Lilly with novel activities to try, such as jumping rope, skiing, swimming, or playing tennis, would

TABLE 8-4 Lilly's Completed Interpretation Worksheet

SENSORY INTEGRATION AND PRAXIS ANALYSIS WORKSHEET							
Visual	**Score**	**Vestibular**	**Score**	**Somatosensory**	**Score**	**Interoception/ **Sensory Modulation**	**Score**
Visual Spatial		**Postural Control		**Proprioception		Sensory responses	
SV	–0.8	SWB	–1.4	KIN	–1.5	Over (tactile, vestibular)	Yes
FG	–0.2	Prone extension	Weak	SWB	–1.4	Under (auditory)	Yes
*Visual Praxis		Postural stability	Fair	Poor body scheme	Yes	Fluctuating	>1SD
DC	–1.9	Righting	Fair	Observations (e.g., finger/nose) Thumb/finger touching	Poor	SPM results	
CPR	–1.6	Equilibrium	Poor	*Tactile		Visual	>2SD
MAC	–0.3	Vestibular-Ocular		LTS	–0.6	Hearing	>2SD
Haptic Form and Space		Low PRN	–0.5	GRA	–0.9	Touch (LTS)	>2SD
MFP part 1	–0.6	Ocular stability	OK	FI	–1.6	Body awareness	>2SD
GRA	–0.9	Head/neck/eye coordination	OK	MFP	–0.6	Balance and motion	>1SD
Observations: Able to do puzzles, prints first name		Bilateral coordination	Poor			SP results	
						Hypersensitive	OK
						Sensory avoiding	OK
		Bilateral Integration	**Score**	****Praxis**	**Score**	Hypo-response	Low
		BMC	–.07	PPr	–2.0	Sensory seeking	OK
		SPr	–2.0	OPr	–1.6	Observations:	
		OPr	–1.6	PrVC	–1.4	Arousal	High at times
		GRA	–0.9	(SPr)	–2.0	Affect	n/a
		MFP part 2	–0.5	(BMC)	–0.7	Activity Level	Good
		MAC	–0.3	Flexion	OK	Attention	Possible concern
		Observations: skipping	Poor	Observations: play, rigid, sedentary	Fair	Low frustration tolerance,	Yes
						mild anxiety	No
Right Hemisphere	**Data**	**Laterality**	**Data**	**Praxis on Verbal Demand**	**Data**	**Left Hemisphere**	**Data**
Low performance IQ	n/a	SVCU	n/a	PrVC (LOW)	n/a	High performance IQ	n/a
High verbal IQ		PHU		PRN (average to high)		Low verbal IQ	
Poor visual spatial		R/L differences		Poor sequencing		Poor sequencing	
Lower left-sided scores		Poor scores on directionality, reversals, inversions, jogs		Possible low scores on: OPr, SPr, BMC, SWB, DC			
Irregular Neurological Signs *Circle if present:* Hyper- or hypotonia, associated movements, clonus, increased PRN, tremors, tics, choreoathetosis, hypersensitivity to movement, seizures, other (specify . . .).							

* means important to your clinical reasoning
** means very important to your clinical reasoning
n/a: not assessed

also be helpful, provided the activities are enjoyable. However, it is important to acknowledge that Lilly may need more time than other children her age to feel comfortable and learn new skills. Exercising patience and providing lots of opportunity for repetition and practice will assist with the pace of her learning.

- Heavy work activities that provide Lilly's body with proprioceptive sensory information would assist in developing body awareness and increase Lilly's level of comfort with movement and motor planning skills. Tug of war, pulling and pushing heavy objects, pedaling a bike, and bouncing on a trampoline are examples of heavy work activities. Imitation games, such as Simon Says and Follow the Leader, and setting up or going through obstacle courses are also good ways to work on motor planning skills.
- As an only child who is home-schooled, Lilly needs to be provided with opportunities to play with other children, and interacting with small groups of children (two or three others) would be ideal. Providing her with some parent or adult support should be considered to assist her in following the play of others and to help her successfully engage and feel comfortable in cooperative, social play situations.

Summary and Conclusions

This chapter discussed the use of the SIPT when conducting comprehensive evaluations of children using a sensory integrative approach. The chapter presented an overview of the test, its purpose, and its psychometric properties. Also presented was the interpretation of SIPT scores in combination with other sources of evaluation data for making clinical decisions regarding diagnosis and for guiding intervention. A case study illustrated how the principles presented throughout the chapter can be applied in practice.

Where Can I Find More?

Training in SI evaluation techniques is available from several sources:

- University of Southern California: http://chan.usc.edu/academics/sensory-integration/continuing-education
- STAR Institute, Denver, CO: https://www.spdstar.org/
- The Spiral Foundation: http://thespiralfoundation.org
- The Collaborative for Leadership in Ayres Sensory Integration (CLASI): https://www.cl-asi.org/
- Thomas Jefferson University, Advanced Certificate in Sensory Integration: http://www.jefferson.edu/university/health-professions/departments/occupational-therapy

References

Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities, 2*(3), 44–52.

Ayres, A. J. (1972). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy, 26*(1), 13–18.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy, 31*(6), 362–366.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (2005). *Sensory Integration and Praxis Tests revised manual*. Los Angeles, CA: Western Psychological Services.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, Y. (2008). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39,* 1–11.

Cermak, S. A., & Murray, E. A. (1991). The validity of the constructional subtests of the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy, 45,* 539–543.

Davies, P. L., & Tucker, R. (2010). Evidence review to investigate the support for subtypes of children with difficulty processing and integrating sensory information. *American Journal of Occupational Therapy, 64,* 391–402.

Dunn, W. (2014). *Sensory Profile 2*. San Antonio, TX: Pearson, PsychCorp.

Fisher, A. (2003). *Assessment of Motor and Process Skills, Vol. 2, User manual* (7th ed.). Fort Collins, CO: Three Star Press.

Law, M., Baptist, S., Carswell, S., McColl, A., Polatajko, H., & Pollock, N. (2005). *Canadian Occupational Performance Measure* (4th ed.). Toronto: CAOT Publications, Canadian Occupational Therapy Association.

Mailloux, Z., Mulligan, S., Smith Roley, S., Blanche, E., Cermak, S., Coleman, G., …Lane, C.J. (2011).

Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy, 65*(2), 143–151.

Mulligan, S. (1996). An analysis of score patterns of children with attention disorders on the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy, 50*(8), 647–654.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy, 52*(10), 819–828.

Mulligan, S. (2000). Cluster analysis of scores of children on the Sensory Integration and Praxis Tests. *Occupational Therapy Journal of Research, 20*(4), 256–270.

Mulligan, S. (2011). Validity of the Postrotary Nystagmus Test as a measure of vestibular function. *OTJR: Occupation Participation and Health, 31*(2), 97–104.

Murray, E. A., Cermak, S. A., & O'Brien, V. (1990). The relationship between form and space perception, constructional abilities, and clumsiness in children. *American Journal of Occupational Therapy, 44,* 623–628.

Parham, L. D. (1998). The relationship of sensory integrative development to achievement in elementary students: Four-year longitudinal patterns. *Occupational Therapy Journal of Research, 18,* 105–127.

Parham, L. D., & Ecker, C. L. (2007). *Sensory Processing Measure (SPM) Home Form*. Los Angeles, CA: Western Psychological Services.

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (1997). Somatosensory functioning in children with attention deficit hyperactivity disorder. *Developmental Medicine and Child Neurology, 39,* 464–468.

Roley, S. (2012). Comprehensive Sensory Integration Certification Program, Course 3 From Interpretation to Intervention, notebook, Western Psychological Services and University of Southern California, Torrance, CA.

Roley, S. S., Mailloux, Z., Parham, D., Schaaf, R. C., Lane, S., & Cermak, S. (2015). Sensory integration and praxis patterns in children with autism. *American Journal of Occupational Therapy, 69,* 69011220010. doi:10.50141ajot.2015.012476

CHAPTER 9

Using Clinical Observations within the Evaluation Process

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If you make listening and observation your occupation you will gain much more than you can by talk.

—Robert Baden-Powell

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Explain the link between sensory integration (SI) theory and the skills evaluated through clinical observations.
- ✔ Describe the role of clinical observations in the evaluation process for detecting sensory processing and praxis difficulties in children.
- ✔ Compare different methods for gathering information through observation.
- ✔ Describe and interpret specific clinical observations for assessing postural tone and control, motor planning and sequencing, bilateral coordination, and reaction to gravity.

Purpose and Scope

A comprehensive evaluation process includes observations of a child's preferred occupations and the skills required to perform them. These observations are referred to as *skilled observations* and may be structured or unstructured. **Clinical observations** is a term widely used to refer to the relatively standard set of structured observations that complement standardized assessment of sensory integrative functioning, often done using the Sensory Integration and Praxis Tests (SIPT; Ayres, 1989). The purpose is to assist in determining factors that interfere with a child's participation in daily activities and interactions in the environment. Structured clinical observations are therapist-directed and involve specific tasks that provide information about posture and motor planning. Most of the structured, formal clinical observations used in comprehensive sensory integration (SI) evaluations were first identified by Ayres (1972; Blanche, 2002, 2010; Bundy & Fisher, 1981) and are, therefore, sometimes referred to as *Ayres Clinical Observations.*

In addition to structured clinical observations, therapists generally include unstructured, or informal, observations in assessment. **Unstructured observation** is a term used in two different ways: (1) in the context of clinical observations to capture the qualitative aspects of motor performance and more elusive functions, such as sensory modulation and regulation, and (2) while a child is freely interacting in a natural environment. Unstructured observations of the second type are particularly important with young children, children who do not follow instructions well, or those who experience difficulty following the protocols necessary when administering standardized assessments.

In this chapter, we describe and illustrate structured clinical observations and the unstructured,

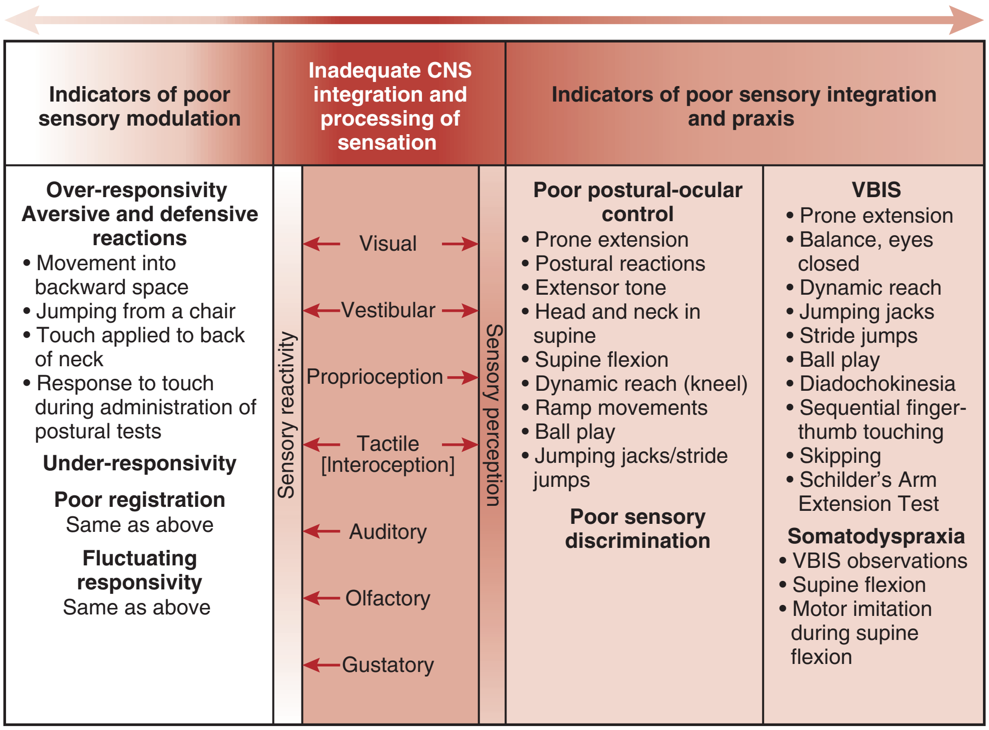

FIGURE 9-1 Relationship of clinical observations to sensory integration theory.

qualitative observations that therapists make, focusing on postural-ocular control and praxis. The importance of clinical observations in the evaluation of SI and praxis lies in the link between the skill being tested and its relationship to SI theory. All the observations reflect a tie—either theoretical or drawn from basic science (Agrup, 2008; Braswell & Rine, 2006; Cohen & Keshner, 1989)—between central nervous system (CNS) functioning and behavior.

Each clinical observation meets a particular purpose. For example, the vestibular system contributes to antigravity extension (Keshner & Cohen, 1989; Markham, 1987). In SI theory, testing antigravity extensor muscle tone is thought to provide insight into vestibular processing. Antigravity extension is tested with the child in the prone position, extending the head, neck, upper trunk, and limbs against gravity (Blanche, 2002, 2010; Bundy & Fisher, 1981; Fanchiang, 1989; Longo-Kimber, 1984; Wilson, Pollock, Kaplan, & Law, 2000; Wilson, Pollock, Kaplan, Law, & Faris, 1992). This chapter describes several useful observations—both structured and unstructured—that therapists can do as part of the evaluation. We link each observation in the interpretation of performance to a function of SI. We illustrate those relationships using the model shown in Figure 9-1. We also cite existing research supporting administration procedures. Readers will find a useful summary of structured and unstructured clinical observations of postural control and praxis in Table 9-1.

While we focus on standardized clinical observations for assessing postural-ocular control and motor planning, a thorough evaluation of SI also includes informal observation of a child's responses to tactile, proprioceptive, and vestibular input. For example, an examiner can identify tactile defensiveness, a difficulty with sensory modulation, by watching a child's response to incidental touch. Such observations often can be conducted in the context of typical play activities or during other activities of daily living (ADLs). Most data from clinical observations are drawn from two types of sources. First, there are protocols that are commercially available, such as the *Clinical Observations of Motor and Postural Skills* (COMPS; Wilson et al., 1992; 2000), which include normative data. Others have described specific methods for administration, through video, and support interpretation

TABLE 9-1 Structured and Unstructured Clinical Observations for Assessing Postural Control and Motor Planning

AREA			INTERPRETATION
I. Axial Postural Control Impacted by Sensory Processing			
Prone Extension	Structured Observations Prone extension	Child assumes a whole body extended posture as indicated and demonstrated by the examiner.	Difficulties relate to decreased aspects of vestibular proprioceptive processing and its effect on extensor tone
	Unstructured Observations a. Swinging in prone	Child is observed during free play on equipment that supports swinging in a prone position (e.g., frog swing).	Same as above
	b. Standing posture	Child's upper trunk position.	Rounded upper back and decreased scapula adduction may be related to decreased antigravity extension
Flexion Against Gravity	Structured Observation Supine flexion	Child assumes a whole body flexed posture as indicated and demonstrated by the examiner.	Somatosensory processing and its relationship to praxis difficulties
	Unstructured Observation a. Holding on a trapeze while lifting lower extremities	Child is observed during free play (e.g., playground structure).	
	b. Standing posture	Poor abdominal activation observed during quiet stance.	
	c. Raising from the floor (supine position)	Child's overall control and abdominal activation is observed and noted.	
Postural Control in Standing	Structured Observations Standing under different conditions	Ability to assume and maintain standing postures with feet together, heel-to-toe, or standing on one foot with eyes open and eyes closed, and using firm and soft surfaces.	Visual, vestibular, and somatosensory contributions to postural control abilities
	Unstructured Observations Play and games in which the child needs to navigate different surfaces and terrains (sand, pillows)	Ability to stabilize his/her body to perform and participate in play in comparison with children of the same age and gender.	
Postural Control in High Kneeling	Structured Observations Reaching for an object while on a high kneeling position	Ability to utilize anticipatory postural control during a weight-shifting task.	Anticipatory postural control

TABLE 9-1 Structured and Unstructured Clinical Observations for Assessing Postural Control and Motor Planning—cont'd

AREA			INTERPRETATION
II. Motor Planning			
Feedback Related	Structured Observations Slow ramp movements	Child is observed performing slow movements. His/her ability to control speed and quality are noted.	Contribution of proprioceptive processing to slow and controlled movements
	Unstructured Observations a. Paper-and-pencil tasks or other tasks requiring the use of tools (eraser, pencil sharpener, folding papers)	The child's ability to stabilize, dissociate, and grade speed and pressure of fine movements is observed and noted.	
	b. Child's ability to organize himself/herself to imitate the positions demonstrated by the examiner	Note performance during all structured clinical observations.	Imitation skills and their relationship to praxis
	c. Play situations or games, such as Simon Says, or at school when a child is expected to imitate or copy the actions of others. Overall performance in comparison with other children of the same age and gender	Naturalistic observation.	
Timing, Feedforward, or Projected Actions in Time and Space	Structured Observations Ball play: Child's ability to anticipate the movement and trajectory of objects	Child's ability to orient his/her body and position himself/herself in preparation for catching, hitting, or making contact.	Feedforward or projected actions in time and space
Sequencing	Structured Observations a. Alternating forearm movements b. Sequential finger touching	Smoothness, fluidity, and isolation of discrete and rhythmic movements. Presence or absence of associated movements.	Movement planning and execution that relates to adequate sensory processing
Bilateral Motor Coordination	Structured Observations a. Skipping b. Series of jumps	Use of bilateral strategy and fluidity of movements. Continuous movements vs. interruptions in between jumps.	Ability to motor plan movements and bilateral motor coordination
Additional Observations of Sensory Processing			
Modified Schilder's Arm Extension Test	Ability to maintain arms outstretched as demonstrated and indicated by the examiner. Ability to dissociate movements of the trunk and upper extremity during head rotations.		Proprioceptive processing
Gravitational Insecurity	Child's comfort during different tasks that challenge his or her relationship to gravity.		Reaction to a variety of sensory experiences

through case analysis, such as *Observations Based on Sensory Integration Theory* (Blanche, 2002, 2010). Second, there are some published research reports that describe a particular observation or group of observations. For example, the prone extension posture has been examined in children with and without reported motor difficulties (Fanchiang, 1989; Longo-Kimber, 1984).

Assessment and Interpretation

Children with SI dysfunction often have difficulty with postural-ocular control. Several authors (Blanche, 2002, 2010; Bundy, 2002; Longo-Kimber, 1984; Wilson et al., 1992, 2000) have suggested assessment procedures. In this section, we outline clinical observations of (1) prone extension; (2) flexion against gravity (i.e., supine flexion); (3) postural control in standing with eyes open and closed, on one foot, and on soft vs. firm surfaces; and (4) dynamic reach in high kneeling.

HERE'S THE POINT

- All assessments (including standardized testing) should include data from observations (structured and unstructured).
- There are specific procedures or protocols used to administer several of the structured clinical observations used during SI evaluations. It is vital that interpretation of performance and analysis of data be based on information obtained from the specific protocol utilized.
- Information collected through the administration of clinical observations can be easily grouped using three categories: postural control [influenced by sensory processing], motor planning, and sensory processing.

Postural-Ocular Control

Postural-ocular control is defined as those functions necessary to maintain proximal stability, postural orientation, and a stable visual field. **Proximal stability** comprises generalized muscle tone and alterations to tone that allow postural reactions in response to the pull of gravity and maintenance of body alignment. **Postural orientation** refers to an appropriate relationship among body segments, the task, and the environment (Shumway-Cook & Woollacott, 2012). It involves our ability to orient body segments to each other and a task. A stable visual field means that while moving the head, the visual field remains still. In this section, we focus on the maintenance of postures.

Postural-ocular control is influenced by anticipatory (feedforward) mechanisms and by adaptive (feedback) mechanisms. **Anticipatory mechanisms** refer to activation of postural muscles in preparation for skilled action. **Adaptive mechanisms** occur when body position is perturbed, necessitating a response to maintain the position (Shumway-Cook & Woollacott, 2012). Evaluating postural control involves the ability to maintain stable positions (quiet stance) as well as the ability to make adaptive postural adjustments during movement.

Prone Extension

Processing of vestibular and proprioceptive sensations is closely linked with the ability to assume and maintain prone extension (Ayres, 1972; Quirós & Schrager, 1978). During this structured observation, the examiner observes quantitative and qualitative behaviors related to assuming and maintaining the posture. The examiner demonstrates (Fig. 9-2) and then instructs the child to assume and maintain the position for as long as possible. The therapist notes both quantitative information (the number of seconds the child can maintain the position) and qualitative information (how easily the child assumes and maintains the position). Asking a child to copy the position introduces an element of motor planning.

Length of time children are expected to maintain the position differs according to the source. Longo-Kimber (1984) indicated that the

FIGURE 9-2 Examiner demonstrating the prone extension position. *Copyright Dominique Kiefer.*

mean length of time that 5-year-olds can maintain prone extension is 63.2 seconds (males) and 48.3 seconds (females), although variability was very high, with a standard deviation (*SD*) of 30.7. Dunn (1981) reported shorter durations for both girls and boys (15 to 20 seconds). Some differences may have been because of sampling characteristics.

More recently, data collected on 90 Caucasian middle-class children between 5 years of age and 7 years, 11 months of age from a metropolitan city in Chile revealed that 5-year-olds maintained prone extension with adequate quality for a mean of 16 seconds (*SD* = 10) (Blanche, Reinoso, & Kiefer, 2015; Imperatore Blanche, Reinoso, Blanche-Kiefer, & Barros, 2016). On the best of two attempts, 6-year-olds maintained the position for 20 seconds (*SD* = 11), and 7-year-olds for 21 seconds (*SD* = 11). These data support previous studies (Harris, 1981; Wilson et al., 2000) in which children 6 years of age and older were able to assume and maintain prone extension without excessive effort.

Qualitative observations of testing provide information about motor planning, muscle tone, and postural control. Qualitative observations include the ability to:

- Assume the position nonsegmentally (lifting arms and legs up simultaneously)
- Hold the head steady and within 45 degrees of vertical
- Lift the upper chest and shoulders off the supporting surface
- Raise the distal one-third of both thighs off the floor
- Maintain the knees in less than 45 degrees of flexion
- Assume and maintain without excessive effort (Blanche et al., 2015; Harris, 1981; Imperatore Blanche et al., 2016; Wilson et al., 2000)

Researchers (Blanche et al., 2015; Harris, 1981; Longo-Kimber, 1984; Wilson et al., 1992, 2000) have shown that both quality of assumption and time maintained differ significantly between typical children and children with known difficulties. Figures 9-3 and 9-4 demonstrate the desired posture and a common incorrect posture, respectively.

Extension against gravity also can be observed informally during free play or when the child utilizes equipment in the clinic, for example, while lying prone on a scooter board or platform swing. Movement provides vestibular input, which should increase extensor tone and help the child assume antigravity extension. Extensor tone can be observed in standing or sitting at a table. In this situation, a rounded upper back, leaning on the whole forearm, laying the head on the table, or excessive scapular abduction may indicate decreased extensor tone and consequent proximal stability.

FIGURE 9-3 Child assuming a correct position of prone extension. *Copyright Dominique Kiefer.*

FIGURE 9-4 Child assuming an incorrect position of prone extension. *Copyright Dominique Kiefer.*

Flexion Against Gravity

The ability to assume and maintain flexion against gravity is critical to postural control and has been linked to somatosensory processing and praxis (Dunn, 1981; Wilson et al., 1992, 2000). Supine flexion includes crossing arms (hands to opposite shoulder) and simultaneous lifting of the upper extremity, head, and legs (see Fig. 9-5). The examiner demonstrates (or gives verbal instruction), and then the child assumes and maintains the position for as long as possible.

FIGURE 9-5 Examiner demonstrating the supine flexion position. *Copyright Dominique Kiefer.*

FIGURE 9-6 Child assumes and maintains supine flexion correctly. *Copyright Dominique Kiefer.*

Researchers have reported substantial variability in typical samples, even within a single age group. Fraser (1983) reported that children from 5 years, 5 months of age to 5 years, 9 months of age held supine flexion for a mean of 39 seconds (*SD* = 32.77; range = 0–120; median = 34), whereas Dunn (1981) found that 5-year-olds maintained for 11 to 20 seconds.

More recent data indicate that on the best of two attempts, 5-year-olds maintained supine flexion for a mean of 24 seconds (*SD* = 20), 6-year-olds for 33 seconds (*SD* = 20), and 7-year-olds for 44 seconds (*SD* = 18; Imperatore Blanche et al., 2016). Preliminary studies of inter-rater reliability using four raters scoring four children by video indicated acceptable agreement on both quantitative and qualitative parameters (Blanche et al., 2015). Even considering the substantial variability across sources and given the mean of 24 ± 20 seconds, 5-year-olds can be expected to assume and maintain supine flexion for a minimum of 4 seconds.

Qualitative observations include the ability to:

- Lift upper and lower extremities simultaneously
- Maintain head in midline with the chin tucked
- Keep shoulders and arms off the supporting surface
- Maintain ankles and knees in flexion
- Keep hands relatively relaxed (i.e., not holding self tightly)
- Maintain without effort

Figure 9-6 demonstrates a child assuming and maintaining the correct position, whereas the children in Figures 9-7 and 9-8 demonstrate difficulty with supine flexion and an inability to assume the position. Antigravity flexion also can be observed during play when the child is hanging from a trapeze and attempts to bring the

FIGURE 9-7 Child assuming supine flexion incorrectly. *Copyright Dominique Kiefer.*

FIGURE 9-8 Child showing significant difficulty assuming supine flexion. *Copyright Dominique Kiefer.*

legs up against gravity, or in standing by observing abdominal control. In most children, an anterior pelvic tilt is absent.

Postural Control in Standing

Observing postural reactions while standing with eyes open and closed provides information about balance deficits (Richardson, Atwater, Crowe, & Deitz, 1992) and the contributions of the vestibular, proprioceptive, and visual systems. Structured observations include standing on one and both feet, firm and soft surfaces, and with eyes open and closed. According to Deitz, Richardson, Atwater, and Crowe (1991), in the *Sensory Interaction for Balance Test,* the specific contribution of each sensory system can be isolated. For example, if a child maintains a standing position on a soft surface with eyes open but falls when standing with eyes closed, the examiner can assume that the child's vestibular system is under-reactive. On the other hand, if having the eyes open or closed makes no difference on maintaining a standing position, the examiner can assume that the child's balance difficulties are of a neuromotor nature. The contributions of the varying systems are presented in Table 9-2.

When using structured observations, the examiner demonstrates and then encourages the child to maintain the position as long as possible. Also, the examiner should note if the child requires physical assistance. Recent data indicate increasing ability with age. Five-year-olds (N = 90) maintained standing with feet together and eyes open on a firm surface for a mean of 23 seconds (SD = 2) whereas 6- and 7-year-olds maintained for a mean of 25 seconds (SD = 1). Inter-rater reliability was good (K = .62), and for the total score, based on intraclass correlation, was very strong (ICC = .91) (Blanche et al., 2015).

Unstructured observations of the ability to assume and maintain a standing position under various conditions provide information about proximal joint stability, muscle tone, and postural strategies. The following can be observed:

- Ankle strategies to maintain equilibrium. **Ankle strategies** are reactions that are observed in the feet in response to weight shifting when balance is challenged (Runge, Shupert, Horak, & Zajac, 1999). Proprioceptive processing is pivotal to these responses.
- Alignment of knees and hips, which depends on proximal joint stability.

Figures 9-9 and 9-10 illustrate adequate alignment on firm and soft surfaces. Figure 9-11

TABLE 9-2 Sensory Contribution to Postural Control while Standing on a Firm and Soft Surface with Eyes Open and Closed

SENSORY CONTRIBUTION	FIRM SURFACE		SOFT SURFACE	
	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
Visual	X		X	
Vestibular	X	X	X	X
Somatosensory (proprioception and tactile)	X	X		

FIGURE 9-9 Child displaying adequate postural control on a firm surface with eyes open. Observe adequate alignment. *Copyright Dominique Kiefer.*

FIGURE 9-10 Child displaying adequate postural control on a soft surface with eyes open. Observe adequate alignment. *Copyright Dominique Kiefer.*

FIGURE 9-11 Child displaying inadequate postural control and alignment when standing on one foot on a soft surface with eyes open. Observe his use of compensatory strategies, such as his left foot pressing against his right leg, hyperextension of the distal joints of his hands, and hiking of the left shoulder in an attempt to stabilize. *Copyright Dominique Kiefer.*

shows a child who is unable to maintain equilibrium on a soft surface.

Observe the individual's use of compensatory strategies such as the left foot pressing against the right leg, hyperextension of distal joints of the hands, and hiking of the left shoulder in an attempt to stabilize.

Dynamic Reach in Standing and High Kneeling

Observations of dynamic reach are based on *The Pediatric Functional Reach Test.* This test was originally described by Duncan and colleagues (1990) and then adapted for a pediatric population (Donahoe, Turner, & Worrell, 1994). Donahoe and colleagues (1994) defined *functional reach* as the maximal greatest distance of reach, beyond arms' length, while remaining standing over a base of support. Donahoe and colleagues reported that 5-year-olds reached forward a mean distance of 15.5 cm (*SD* = 4.4). Similar tests were reported by Fisher (1991) for measuring balance while standing on a stable surface or tilt board and reaching. Imperatore Blanche and colleagues (2016) adapted this test for high kneeling with a sample of children between 5 years of age and 7 years, 11 months of age. Recent data indicate that children without reported difficulties reached 15 to 20 cm diagonally without difficulty and that the observation could be scored reliably among independent raters (Imperatore Blanche et al., 2016). Figure 9-12 shows an occupational therapist assessing dynamic reach in a high kneeling position. Note that this child has reached so far forward that she needs to compensate by moving her head backward.

FIGURE 9-12 Child using postural control skills during a high kneeling reach task. *Copyright Dominique Kiefer.*

HERE'S THE POINT

- Postural-ocular control is reliant on proximal (trunk) stability, knowledge of the relationship between body segments, and a stable visual field.
- Prone extension and supine flexion can be assessed to support an understanding of postural control.
- Balance can be examined through observation of postural reactions using soft and firm surfaces and by looking at balance on both feet and each separately. The role of vision in balance reactions can be determined by considering the child's ability to balance with his or her eyes open and closed.
- Dynamic reach offers another way to examine active postural-ocular control.

Motor Planning

Assessment of motor planning is another major area in which structured clinical observations can be helpful. These observations include tasks that are relatively feedback- and feedforward-dependent as well as those that involve sequencing and bilateral motor coordination. Examples of clinical observations targeting feedback-dependent movements include slow ramp movements and informal observations of motor imitation. Feedforward-dependent tasks include ball play or anticipating an interaction with a moving object. Sequenced actions include alternating forearm movements (diadochokinesis) and sequential thumb-to-finger touching. Bilateral coordination is assessed during jumping jacks, skipping, and stride jumps.

HERE'S THE EVIDENCE

Kooistra and colleagues (2009) examined children with fetal alcohol spectrum disorder (FASD) and children with attention deficit-hyperactivity disorder (ADHD) to determine if different motor profiles could be established to reflect the two diagnostic groups and typical children. They included 116 children, 7 to 10 years of age, in this study, and the researchers assessed them using, among other tools, the *Movement Assessment Battery for Children* (M-ABC; Henderson & Sugden, 2007), COMPS (Wilson et al., 2000), and clinical measures of balance. Included on the COMPS are the following observations: slow (ramp) movements, rapid forearm rotation (dysdiadochokinesis), finger–nose touching, prone extension posture, asymmetrical tonic neck reflex, and supine flexion. Although the M-ABC failed to distinguish between groups, performance on the COMPS differed among groups. Children with ADHD performed less well than the children in the typical comparison group, and those children had motor and postural deficits that were within the clinical range. The performance of children with FASD was more likely to be typical on these basic motor functions. Both diagnostic groups showed balance deficits, which suggests that basic motor performance skills may help differentiate between these diagnostic groups; children with ADHD showed difficulty with both complex and basic motor skills, whereas children with FASD showed deficits primarily in complex skills.

Summarized from Kooistra, L., Ramage, B., Crawford, S., Cantell, M., Wormsbecker, S., Gibbard, B., & Kaplan, B.J. (2009). Can attention deficit hyperactivity disorder and fetal alcohol spectrum disorder be differentiated by motor and balance deficits? *Human Movement Science, 28*(4), 529–542.

Feedback-Dependent Tasks

Feedback-dependent tasks involve ongoing modification because of sensory feedback (Seidler, Noll, & Thiers, 2004). Feedback control is inherently slow because of the high degree of accuracy and the need for error correction

(Seidler et al., 2004). Therefore, only some movements can be performed using feedback-control. Clinical observations of feedback-dependent movements include slow ramp movements and imitation of body positions demonstrated by the examiner. When observing a child imitating a position, the clinician should attend to the strategies the child uses and to the nature of any errors.

Slow Ramp Movements

Slow ramp movement tests involve mirroring the smooth, fluid, slow movements of the examiner. The examiner begins with shoulders and arms abducted, elbows extended, forearms supinated, wrists in a neutral position, and fingers extended. The examiner then moves his or her hands to the shoulders and returns to the starting position using controlled, smooth, fluid motions. Movement in each direction should take about 5 seconds or 10 seconds total (Fig. 9-13). The child faces the examiner and copies the examiner's movements at exactly the same speed. The examiner observes:

- Speed of movement (i.e., Does the child complete the movements at the same time? Within 2 to 3 seconds? More than 3 seconds difference?)
- Symmetry of movements (right and left)
- Fluidity of movements
- Ability to perform movements without visual feedback

Recent data indicate that children between 5 and 7 years of age are able to perform this task with ease, matching the speed of the examiner's movements within a mean of 1.5 seconds (Imperatore Blanche et al., 2016). Dunn (1981) reported similar results in 5-year-olds. The ability to imitate following a visual presentation or demonstration without verbal directions is easier than performing following verbal commands (Zoia, Pelamatti, Cuttini, Casotto, & Scabar, 2002). Figures 9-14 and 9-15 show examples of poor performance of this task, where children were unable to move their arms simultaneously and unable to match the speed of movement with the examiner.

FIGURE 9-14 Failure to move simultaneously. *Copyright Dominique Kiefer.*

FIGURE 9-13 Slow ramp movements. Note the symmetry and simultaneous performance. *Copyright Dominique Kiefer.*

FIGURE 9-15 Failure to move simultaneously. *Copyright Dominique Kiefer.*

Motor Imitation: Copying Postures

Imitation of Postures is one of the standardized tests of praxis included in the SIPT (Ayres, 1989). Imitation also can be observed when a child copies an examiner assuming prone extension or supine flexion postures. Both the strategies used by the child and the outcome of a child's attempts can be noted. Children with motor planning difficulties may verbally direct their movements or assume the position segmentally or incorrectly.

Feedforward-Dependent Actions, Including Projected Actions Sequences

Fisher (1991) related the ability to perform anticipatory movements that depend on feedforward control to vestibular and proprioceptive processing. **Feedforward-control** (i.e., the ability to initiate an action before feedback is available) is required when either a child is moving or the target that the child is acting on is moving, or both (Fig. 9-16). Feedforward control is particularly important in actions where timing and sequencing of movements are crucial. Successful completion of feedforward-dependent tasks involves sequences of actions that enable one to get the whole body or the hands or feet to the place where the action is to occur at the time when the action needs to occur. If a child waits too long to move his hands toward an oncoming ball, the child will fail to catch the ball. Observing feedforward-dependent actions, which by definition require timing and sequencing, is an integral component of an evaluation of praxis. In everyday life, feedforward control is required during activities such as playing ball games, jumping rope, crossing the street, walking through a crowded space, or avoiding obstacles while riding a bicycle.

FIGURE 9-16 Child throwing a medium-size ball up in the air and clapping before catching the ball. *Copyright Dominique Kiefer.*

Ball Play

The ability to perform feedforward-dependent anticipatory movements effectively is often observed in clinical observations in the context of catching or kicking a ball. Standardized tests of motor proficiency, such as the M-ABC (Henderson & Sudgen, 2007) and the *Bruininks-Oseretsky Test of Motor Proficiency, Second Edition* (BOT-2) (Bruininks & Bruininks, 2005), can also be used to assess these skills and provide normative information about the speed and accuracy of performance. However, such tests only indirectly consider qualitative performance.

Gubbay (Gubbay, 1975; Gubbay, Ellis, Walton, & Court, 1965) developed a test in which children repeatedly throw a tennis ball in the air, clap, and then catch the ball as many times as possible in 30 seconds. In a variation of this task, a child throws a tennis or medium-size ball in the air, claps up to three times, and then catches the ball (see Fig. 9-16). Children identified as having sensory integrative dysfunction often are unable to perform this task (Imperatore Blanche et al., 2016). On the best of two attempts, 5-year-olds clapped a mean of 1.25 times (*SD* = 0.4) before catching the ball; 6-year-olds clapped twice (*SD* = 0.8); and 7-year-olds clapped 2.5 times (*SD* = 0.9). Inter-rater reliability as noted with the other clinical observations was within acceptable standards (Blanche et al., 2015).

Sequencing

Sequencing is integral to motor planning. All feedforward-dependent tasks involve sequencing actions. Some clinical observations, however, involve repeated sequences of movements. These provide opportunities for evaluating fluidity and sequencing of movements. To that end, we assess rapidly alternating forearm movements (**diadochokinesis**) and sequential finger touching.

Rapidly Alternating Forearm Movements

Clinical observation of diadochokinesis involves performing rapid forearm pronation and supination with each arm separately and then the two simultaneously. Quality of movement is important; it should be fluid, rhythmic, and performed without excessive shoulder movement (i.e., internal rotation or abduction). Poor performance or associated (i.e., mirroring) movements in the other hand during unilateral performance reflect a high degree of effort and suggest difficulty. Figure 9-17 shows an examiner assessing alternating forearm movements, and Figure 9-18 shows a child with excessive shoulder rotation and abduction.

Recent data collected with typically developing children indicated that on the best of two attempts, 5-year-olds performed a mean of 4.8 sequences in 5 seconds (*SD* = 1.0), 6-year-olds completed 5.3 sequences (*SD* = 1.1), and 7-year-olds did 6.1 sequences (*SD* = 1.0). Left, right, and bilateral scores were similar. Measures of reliability indicate substantial agreement among independent raters (Imperatore Blanche et al., 2016).

Researchers (Denckla, 1973; Wolf, Gunnoe, & Cohen, 1985) have found that children who have difficulty with diadochokinesia also have poor academic performance. The ability to perform diadochokinesia also discriminates between children with and without disabilities. The reason for this link is unclear except that it may reflect common neurological underpinnings.

FIGURE 9-17 Child demonstrating symmetrical movements without shoulder rotation. *Copyright Dominique Kiefer.*

Sequential Finger Touching

Sequential Finger Touching (SFT) involves moving fluidly when touching the thumb to the tip of each digit, first with one hand and then the other. The child begins by touching the index finger to the thumb. When he reaches the fifth digit, he reverses direction, touching the fifth digit only once. He touches each finger again, ending with the index finger. Six-year-olds can easily perform SFT, and girls generally perform better than boys (Denckla, 1973; Grant, Boelsche, & Zin, 1973). Skillful performance of SFT relies on proprioceptive feedback. The examiner first demonstrates the desired movement and then prevents the child from using visual feedback by placing a screen between the child's head and hand (see Figs. 9-19 and 9-20). Evaluation of the quality of SFT includes observation of:

FIGURE 9-18 Excessive shoulder rotation and abduction during alternating forearm rotation. *Copyright Dominique Kiefer.*

FIGURE 9-19 Examiner demonstrating correct placement of screen when assessing sequential finger touching. *Copyright Dominique Kiefer.*

FIGURE 9-20 Child displaying associated (mirror) movements in opposite hand. *Copyright Dominique Kiefer.*

- Fluidity of movement
- Uniform pressure
- No associated (or mirror) movements in the opposite (resting) hand

Recent data indicate that values for the right hand are similar to the left. Five-year-olds had a mean score of 4.9 touches in 5 seconds (*SD* = 2.3), 6-year-olds had 5.3 touches (*SD* = 2.3), and 7-year-olds had 7.4 touches (*SD* = 2.1). Inter-rater reliability for the counting number of touches was moderate but for evaluation of fluidity was very high (Imperatore Blanche et al., 2016).

Bilateral Motor Coordination

Bilateral motor coordination is evaluated with some subtests of the SIPT (Ayres, 1989) and also can be observed with structured and unstructured clinical observations. Unstructured observations of bilateral motor coordination include observation of tasks that require both hands, such as using one hand to hold the paper while writing with the other, opening a jar, and zipping pants or a jacket. Many tasks that require bilateral motor coordination, such as riding a bike or a scooter, also require timing and anticipatory movements. Structured clinical observations of bilateral motor coordination include observing the quality of performance of skipping, jumping jacks, symmetrical stride jumps, and reciprocal stride jumps (Magalhaes, Koomar, & Cermak, 1989). The examiner demonstrates all skills and should take care to do so fluidly.

Skipping

Most children have learned to skip by the time they enter kindergarten. To evaluate skipping, the examiner demonstrates a fluid, continuous sequence for approximately 5 seconds. Skipping requires bilateral motor coordination and fluid movements. Children with poor praxis often "stop" between skips or have difficulty bouncing from one foot to the other. Data indicate that typically developing 5-year-olds skipped a mean of 5.6 times in 5 seconds (*SD* = 4.1), whereas 6-year-olds skipped 5.3 times in 5 seconds (*SD* = 4.5), and 7-year-olds performed 7.5 skips in 5 seconds (*SD* = 4.6) (Imperatore Blanche et al., 2016). Inter-rater reliability for both qualitative and quantitative parameters was assessed to be acceptable (Blanche, Bodison, et al., 2012).

Jumping Jacks and Stride Jumps

Jumping Jacks. Beginning with arms at the sides and feet together, the examiner does a series of jumps in place. On the first jump, the examiner simultaneously abducts legs and arms until hands clap overhead. Immediately, the examiner jumps up again, returning arms and legs to the starting position. The examiner repeats these jumps a few times continuously and fluidly. Having seen the demonstration, the child performs the same movements, and the examiner evaluates the quality of the jumping jacks. See Figures 9-21 and 9-22 for correct and incorrect performance of jumping jacks.

Symmetrical Stride Jumps. The examiner begins with the arm and leg on the same side forward (e.g., right arm and right foot forward). The examiner jumps rhythmically in place, moving the arm and leg that were forward to the back and bringing the other arm and leg forward. The ipsilateral arm and leg move together throughout the sequence. Having seen the demonstration, the child performs the same movements, and the examiner evaluates the quality of the symmetrical stride jumps.

Reciprocal Stride Jumps. The examiner begins with the contralateral arm and leg forward (e.g., right hand and left foot). The examiner jumps rhythmically in place, moving the arm and leg that were forward to the back and bringing the other arm and leg forward. The contralateral arm and leg move together throughout the sequence. Having seen the demonstration, the child

FIGURE 9-21 Jumping jacks: Correct position. Child completes movement by clapping hands overhead. *Copyright Dominique Kiefer.*

FIGURE 9-22 Jumping jacks: Incorrect position. *Copyright Dominique Kiefer.*

performs the same movements, and the examiner evaluates the quality of the reciprocal stride jumps. Figures 9-23 and 9-24 illustrate symmetrical and reciprocal stride jumps, respectively.

Several qualitative observations can be made during this task:

- Need for assistance to assume the position
- Fluidity and rhythmicity of movements
- Simultaneous movement of correct (i.e., ipsilateral or contralateral) extremities

The ability to perform jumping jacks appears to mature by the time a child is 7 years of age. Stride jumps are more difficult and should not be expected in children younger than 8 or 9 years old (Magalhaes et al., 1989). Bilateral jumps involving both arms and legs are included in the *Bruininks-Oseretsky Test of Motor Proficiency, Second Edition* (Bruininks & Bruininks, 2005). Recent data indicate that 5- and 6-year-olds have difficulty with these jumping tasks and there is a lot of variability of performance. Seven-year-olds had a mean score of 6.2 jumping jacks ($SD = 4.5$), 6.2 symmetrical stride jumps ($SD = 4.7$), and 4.4 reciprocal stride jumps ($SD = 4.4$) (Blanche et al., 2015).

HERE'S THE POINT

- The use of feedback (proprioceptive, visual) in support of the production of action can be observed in slower movements that allow for error correction.
- Feedforward control (vestibular, proprioceptive) is used for movements requiring anticipation, and it is dependent on time and sequencing.
- Bilateral motor coordination should take into account quality in the performance of tasks requiring use of both sides of the body.

Additional Observations of Sensory Processing

When evaluating sensory processing in children, the therapist needs to have multiple data points that indicate a deficit. Difficulty with one observation may or may not be indicative of a problem. Therefore, it is important to include

FIGURE 9-23 Child demonstrating symmetrical stride jumps. *Copyright Dominique Kiefer.*

FIGURE 9-24 Child demonstrates reciprocal stride jumps. *Copyright Dominique Kiefer.*

other measures to establish a clear pattern of dysfunction. Three additional observations addressing primarily proprioceptive, vestibular, and tactile difficulties are described next.

Modified Schilder's Arm Extension Test

To administer the *Modified Schilder's Arm Extension Test* (Blanche, 2002, 2010; Dunn, 1981), the examiner stands behind the child and instructs the child to maintain the arms in 90 degrees of shoulder flexion, with elbows fully extended and forearms pronated. The examiner then places her hands on the sides of the child's face, covering the child's eyes with her fingers. Reminding the child to maintain the position of the body and arms, the examiner rotates the child's head. The following observations can be made:

- Ability to maintain position of upper extremities
- Ability to allow the head to be moved without also rotating the trunk (record: 0 degrees of rotation, 0–45 degrees of rotation, 45–90 degrees of rotation, or 90+ degrees of rotation)
- Ability to keep upper extremities in the starting position
- Ability to maintain equilibrium
- Freedom of movement of the head
- Fingers and hands kept still

According to Dunn (1981), 5-year-olds should rotate the trunk no more than 45 degrees when the examiner turns the head 90 degrees. Younger children are less likely to be able to hold the body position, but older children should find it easier. Difficulties with maintaining the head and upper extremities in position suggest difficulties with proprioceptive processing. Loss of equilibrium suggests vestibular and proprioceptive difficulties. Choreoathetoid movements in the fingers may indicate neuromotor involvement (Ayres, 1977). Figures 9-25 and 9-26 illustrate some of the qualitative observations just mentioned.

FIGURE 9-25 Examiner demonstrates administration of Modified Schilder's Arm Extension Test. *Copyright Dominique Kiefer.*

FIGURE 9-26 Child has poor ability to maintain trunk and arm position. *Copyright Dominique Kiefer.*

For example, the girl's body positioning in Figure 9-25 illustrates an asymmetrical slight drop of upper extremities; the boy in Figure 9-26 seems to have considerable difficulty with proprioceptive processing. In response to head turn, he rotates his trunk more than 90 degrees, flexes his elbows, and supinates in the left forearm.

FIGURE 9-27 Child demonstrates no resistance to backward tilting. *Copyright Dominique Kiefer.*

Gravitational Insecurity

Recall from Chapter 3 (Composing a Theory: An Historical Perspective) that *gravitational insecurity* is defined as fear of changing body position, having the feet off the ground, or moving into backward space (Blanche, 2002, 2010). The fear is out of proportion to the challenge and not caused by poor postural control. Gravitational insecurity has been linked to poor integration of proprioceptive, visual, and vestibular input. May-Benson and Koomar (2007) described two tests to measure gravitational insecurity. The first involves tilting the child backward in space, and the second asks the child to jump off a chair with eyes closed. Qualitative observations that can be made during these tests include the following:

- How comfortable is the child with being tilted backward?
- Does the child resist tilting or show negative emotions, such as anxiety, fear, or distress?
- Does the child firmly grasp the therapist's arms?

When performing these tests, the examiner also should observe postural control. Figures 9-27

FIGURE 9-28 Child seems to enjoy moving into backward space. *Copyright Dominique Kiefer.*

FIGURE 9-29 Child grasps the therapist's arms, suggesting fear of being tipped backward. *Copyright Dominique Kiefer.*

and 9-28 show children with no resistance to, or fear of, being tipped backward. In contrast, the child in Figure 9-29 shows signs of fear, whereas the reaction of the child in Figure 9-30 suggests poor postural control but no fear or resistance.

Under- and Over-Responsivity to Tactile Sensations

Reactivity to tactile sensations can be observed in a variety of ways during the administration of clinical observations. Under-reactivity can be determined if the child fails to orient to light touch applied to the back of the neck (Ayres & Tickle, 1980). Over-responsivity may be observed when providing hands-on physical assistance during the administration of the postural measures or the *Modified Schilder's Arm Extension Test,* when handling the child on a ball, or when providing the opportunity to play with tactile media, such as sand and shaving cream. Tactile reactivity can limit a child's ability to engage in situations that can be socially and motorically demanding.

FIGURE 9-30 Child with postural control difficulties, but no resistance to gravitational challenges. *Copyright Dominique Kiefer.*

HERE'S THE POINT

- Using the Modified Schilder's Arm Extension Test provides an additional way to examine vestibular and proprioceptive processing. This observation also provides insight into neuromotor control.
- Assessing gravitational insecurity provides a means of looking at the modulation of vestibular inputs.
- Observation of the child's response to touch during clinical observations and standardized assessments provides insights into tactile over- and under-responsivity.

Interpretation of Results

Two points are particularly relevant with regard to interpretation. First, any interpretation depends on a high-quality assessment. A high-quality assessment means that structured observations were administered properly and that normative data were applied when available. We have presented some normative data from a variety of sources, including performance expectations of typically developing children at varying ages, although some of the normative data presented is outdated. When norms are not available, therapists must rely on a solid understanding of normal development. Second, accurate interpretation depends on in-depth understanding of SI theory, including the ways in which these clinical observations reflect the theory. Readers are encouraged to understand the relationships of the clinical observations to the constructs associated with SI. See Figure 9-1, and refer back to Figure 1-1.

PRACTICE WISDOM

Clinical observations should be included in all assessments (Asher, Parham, & Knox, 2008) as the use of observations (structured and unstructured) provides a clinician with information that cannot be gathered any other way. Clinical observations in SI are incorporated into professional practice by using commercially available protocols with normative data, such as the COMPS (Wilson et al., 2000), or by applying resources that guide therapist clinical reasoning and analysis, such as educational videos, in-depth observation protocols, and case analysis (Blanche, 2002, 2010). Evidence-based information also can be used from research reports, such as those that have been written by researchers who have investigated a particular observation or group of observations. Finally, the value of augmenting assessment data with naturalistic, unstructured observations for intervention planning cannot be overestimated. Determining how a child's underlying sensory processing and integration abilities are supporting or limiting his or her ability to perform in the natural context, to play, and to succeed at school is key to designing effective programs.

Summary and Conclusions

This chapter reviewed the administration and interpretation of clinical observations, focusing on postural control, motor planning, and sensory reactivity as they relate to sensory processing difficulties. Structured and unstructured clinical observations are part of any evaluation of sensory processing. Observations become essential when standardized data is not available, specifically with young children and children with autism spectrum disorders (ASD). Assessments of SI generally include standardized testing as well as both structured and unstructured clinical observations. There are many reasons why clinical observations are important, but the most important may be that many postural control functions that are thought to reflect vestibular-proprioceptive functioning are not well captured in standardized tests, such as the SIPT. In addition, many young children or children with diagnoses such as autism or ADHD may be unable to complete the SIPT in a valid way. Thus, the identification of sensory integrative deficits must be made largely based upon skilled clinical observations and parent report. Information collected using clinical observations was described in this chapter as it related to postural control, motor planning or praxis, and reaction to sensory information.

Researchers have developed standard procedures for administering many of the structured clinical observations used during SI evaluations. Those researchers also have provided preliminary normative data for those observations. It is vital that interpretation of data based on clinical observations be used and interpreted judiciously as there is great variability in the performance of many of these observable behaviors, particularly among young children.

Where Can I Find More?

Until now, clinical observation has been used as a diagnostic tool, but its use can be expanded to its application as an outcome measure for postural control and motor planning. In such a case, caution is necessary as studies utilizing clinical observations as outcome measures have had mixed results. In administering clinical observations, the following resources may be of assistance.

Videos:

Observations Based on Sensory Integration Theory
Author: Erna Blanche, PhD, FAOTA, OTR/L
Skilled observations of sensory integrative dysfunction allow therapists to discreetly analyze a child's behavior and skills and, in turn, develop more effective intervention plans. This DVD set provides guidelines for clinical observation and nonstandardized assessment. Dr. Erna Blanche shows therapists how to observe and interpret children's behavior from an SI perspective. The DVD and accompanying workbook show, step-by-step, how to administer specific observations, including

those originally defined by Dr. A. Jean Ayres. These are specific tasks, postural responses, and signs of nervous system integrity associated with sensory integrative functioning. Children's skills are compared using split-screen images and in-depth discussion. The workbook provides a table of observations, normative information, a glossary, references, and worksheets that support the learning process. The observations demonstrated can be used with children of varying ages and skill levels.

Written Materials:

Clinical Observations of Motor and Postural Skills: Second Edition (COMPS)

Author: Brenda Wilson, MS, OT (C); Bonnie Kaplan, PhD; Nancy Pollock, MSc, OT (C); and Mary Law, PhD, OT (C)

A screening tool based on six of the clinical observations developed by Dr. A. Jean Ayres. It generates a score to help identify several subtle motor coordination problems in children. This revision now includes children from 5 years of age to 15 years of age. COMPS offer standardized administration procedures and objective criteria for scoring. Easy-to-follow instructions and illustrations help therapists to administer the test quickly and reliably in fewer than 15 minutes. It includes the Scoremaker software to assist with scoring.

References

Agrup, C. (2008). Immune-mediated audio-vestibular disorders in the pediatric population: A review. *International Journal of Audiology, 47,* 560–565.

Asher, V., Parham, L. D., & Knox, S. (2008). Interrater Reliability of Sensory Integration and Praxis Tests (SIPT) score interpretation. *American Journal of Occupational Therapy, 62,* 308.

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1977). Effect of sensory integrative therapy on the coordination of children with choreoathetoid movements. *American Journal of Occupational Therapy, 31,* 591–593.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests. Test manual*. Los Angeles, CA: Western Psychological Service.

Ayres, A. J., & Tickle, L. (1980). Hyper-responsivity to touch and vestibular stimuli as a predictor of positive response to sensory integration procedures by autistic children. *American Journal of Occupational Therapy, 34,* 375–381. doi:105014/ajot.34.6.375

Blanche, E. I., Bodison, S., Chang, M., & Reinoso, G. (2012). Development of the Comprehensive Observations of Proprioception: Validity, reliability and factor analysis. *American Journal of Occupational Therapy, 66*(6), 691–698. doi: 10.5014/ajot.2012.003608

Blanche, E. I. (2002, 2010). *Observations based on sensory integration theory*. Torrance, CA: Pediatric Therapy Network.

Blanche, E. I., Reinoso, G., & Kiefer, D. B. (2015). *Observaciones clínicas sensorio-motoras. Training manual*. Los Angeles, CA: Sensory Metrics.

Braswell, J., & Rine, R. M. (2006). Evidence that vestibular hypofunction affects reading acuity in children. *International Journal of Pediatric Otorhinolaryngology, 70*(11), 1957–1965.

Bruininks, R. H., & Bruininks, D. B. (2005). *Bruininks–Oseretsky Test of Motor Proficiency* (2nd ed.). Minneapolis, MN: Pearson Assessment.

Bundy, A. C. (2002). Assessing sensory integration dysfunction. In A. C. Bundy, S. J. Lane, & E. A. Murray (Eds.), *Sensory integration: Theory and practice* (pp. 169–198). Philadelphia, PA: F.A. Davis.

Bundy, A. C., & Fisher, A. G. (1981). The relationship of prone extension to other vestibular functions. *American Journal of Occupational Therapy, 35,* 782–787.

Cohen, H., & Keshner, E. A. (1989). Current concepts of the vestibular system reviewed: Visual/vestibular interaction and spatial orientation. *American Journal of Occupational Therapy, 43,* 331–338.

Deitz, J. C., Richardson, P., Atwater, S. W., & Crowe, T. K. (1991). Performance of normal children on the Pediatric Clinical Test of Sensory Interaction for Balance. *OTJR: Occupation, Participation and Health, 11*(6), 336–356.

Denckla, M. B. (1973). Development of speed in repetitive and successive finger movements in normal children. *Developmental Medicine & Child Neurology, 15*(5), 635–645.

Donahoe, B., Turner, D., & Worrell, T. (1994). The use of functional reach as a measure of balance in healthy boys and girls aged 5–15. *Pediatric Physical Therapy, 6*(4), 189–193.

Duncan, P. W., Weiner, D. K., Chandler, J., & Studenski, S. (1990). Functional reach: A new clinical measure of balance. *Journal of Gerontology, 45*(6), M192–M197.

Dunn, W. (1981). *A guide to testing clinical observations in kindergartners*. Rockville, MD: American Occupational Therapy Association.

Fanchiang, S. C. (1989). *Validation of the ocular pursuits, prone extension, and supine flexion clinical observations*. Unpublished master's thesis. Los Angeles, CA: University of Southern California.

Fisher, A. G. (1991). Vestibular proprioceptive processing and bilateral integration and sequencing deficits. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration. Theory and practice*. Philadelphia, PA: F.A. Davis.

Fraser, A. (1983). *Standardization of the supine flexion test in children ages 4–8*. Unpublished master's thesis. Los Angeles, CA: University of Southern California.

Grant, W.W., Boelsche, A.N., & Zin, D. (1973). Developmental patterns of two motor functions. *Developmental Medicine and Child Neurology,15*(2), 171–177.

Gubbay, S. S. (1975). *The clumsy child: A study of developmental apraxic and agnosic ataxia* (Vol. 5). St. Louis, MO: WB Saunders C.

Gubbay, S. S., Ellis, E., Walton, J. N., & Court, S. D. M. (1965). Clumsy children, study of apraxic and agnostic defects in 21 children. *Brain, 88,* 295.

Harris, N. P. (1981). Duration & quality of the prone extension position in 4, 6, 8 year old normal children. *American Journal of Occupational Therapy, 35,* 178–195.

Henderson, S., & Sugden, D. A. (2007). *Movement Assessment Battery for Children* (2nd ed.). San Antonio, TX: Psychological Corporation.

Imperatore Blanche, E., Reinoso, G., Blanche-Kiefer, D., & Barros, A. (2016). Desempeño de niños típicos entre 5 y 7.11 años de edad en una selección de observaciones clínicas: Datos preliminares y propiedades psicométricas en una muestra Chilena. *Revista Chilena de Terapia Ocupacional, 2016*(1), 17–26.

Keshner, E. A., & Cohen, H. (1989). Current concepts of the vestibular system reviewed: 1. The role of the vestibulospinal system in postural control. *American Journal of Occupational Therapy, 43,* 320–330.

Kooistra, L., Ramage, B., Crawford, S., Cantell, M., Wormsbecker, S., Gibbard, B., & Kaplan, B.J. (2009). Can attention deficit hyperactivity disorder and fetal alcohol spectrum disorder be differentiated by motor and balance deficits? *Human Movement Science, 28*(4), 529–542.

Longo-Kimber, J. (1984). The duration and quality of the prone extension position in five and seven year old normal children. *Canadian Journal of Occupational Therapy, 51*(3), 127–130.

Magalhaes, L. C., Koomar, J. A., & Cermak, S. A. (1989). Bilateral motor coordination in 5-to-9 year old children: A pilot study. *American Journal of Occupational Therapy, 43,* 437–443.

Markham, C. H. (1987). Vestibular control of muscular tone and posture. *Le journal Canadien des sciences neurologiques, 14*(3 Suppl), 493–496.

May-Benson, T. A., & Koomar, J. A. (2007). Identifying gravitational insecurity in children: A pilot study. *American Journal of Occupational Therapy, 61,* 142–147.

Quirós, J. B., & Schrager, O. L. (1978). *Neuropsychological fundamentals in learning disabilities*. Novato, CA: Academic Therapy Publications.

Richardson, P. K., Atwater, S. W., Crowe, T. K., & Deitz, J. C. (1992). Performance of preschoolers on the pediatric clinical test of sensory interaction for balance. *American Journal of Occupational Therapy, 46,* 793–800.

Runge, C. F., Shupert, C. L., Horak, F. B., & Zajac, F. E. (1999). Ankle and hip postural strategies defined by joint torques. *Gait and Posture, 10,* 161–170. doi:10.1016/S0966-6362(99)00032-6

Seidler, R. D., Noll, D. C., & Thiers, G. (2004). Feedforward and feedback processes in motor control. *Neuroimage, 22*(4), 1775–1783.

Shumway-Cook, A., & Woollacott, M. H. (2012). *Motor control: Translating research into clinical practice* (4th ed.). Baltimore, MD: Williams and Wilkins.

Wilson, B. N., Pollock, N., Kaplan, B. J., & Law, M. (2000). *Clinical Observations of Motor and Postural Skills* (2nd ed.). Framingham, MA: Therapro.

Wilson, B. N., Pollock, N., Kaplan, B. J., Law, M., & Faris. P. (1992). Reliability and construct validity of the Clinical Observations of Motor and Postural Skills. *American Journal of Occupational Therapy, 46,* 775–783.

Wolf, P. H., Gunnoe, C., & Cohen, C. (1985). Neuromotor maturation and psychological performance: A developmental study. *Developmental Medicine & Child Neurology, 27,* 344–354.

Zoia, S., Pelamatti, G., Cuttini, M., Casotto, V., & Scabar, A. (2002). Performance of gesture in children with and without DCD: Effects of sensory input modalities. *Developmental Medicine & Child Neurology, 44*(10), 699–705.

CHAPTER 10

Assessing Sensory Integrative Dysfunction without the SIPT

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True genius resides in the capacity for evaluation of uncertain, hazardous, and conflicting information.

—Winston Churchill

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Identify aspects of the Bruininks-Oseretsky Test of Motor Proficiency-2, and the Movement ABC-2, and Clinical Observations that can be used to assist in detecting dyspraxia, somatosensory processing problems, and postural and ocular-motor dysfunction in children.
- ✔ Describe the limitations of conducting comprehensive evaluations of sensory integration (SI) without the administration of the Sensory Integration and Praxis Tests (SIPT).
- ✔ Describe how caregiver questionnaires, such as the Sensory Profile and Sensory Processing Measure, can be used to attain important information regarding a child's sensory processing abilities and challenges.

Purpose and Scope

Although the Sensory Integration and Praxis Tests (SIPT) (Ayres, 1989) remains the most comprehensive and psychometrically sound means to assess sensory integration (SI) and praxis in children, their use is not always possible or practical. The purpose of this chapter is to consider other tools that might offer insight into aspects of SI and processing, and the relationship between sensory integrative dysfunction, occupation, and participation. It is not our intent to present all possible assessment tools; that would be a formidable task for this chapter. Instead, we touch on some of the tools typically used to obtain insight into difficulties with sensory modulation, sensory discrimination, and dyspraxia and then provide our thoughts on their strengths and weaknesses relative to understanding sensory integrative dysfunction. Throughout the chapter, we apply some of the tools described and then explain our clinical reasoning with a case, Lenard.

Introduction

There may be multiple reasons for not choosing to use the SIPT to assess sensory integrative dysfunction. One important reason is that the level of detail provided by the SIPT often far exceeds what is necessary for providing the type of intervention that would be most beneficial for a particular child. For example, if a therapist wishes to consult with a teacher to minimize difficulties the teacher is experiencing while instructing a child, most likely it would not be necessary to know the child's scores on the SIPT. The expense associated with administering, scoring, and interpreting the SIPT is another reason that its use is sometimes impractical or impossible. This may be particularly true outside North America, where there is little, if any, local normative data. This situation would require that scores be interpreted very cautiously, as the potential effects of culture on performance are largely unknown. The idea of using an expensive SIPT without being certain how well the norms apply may be incomprehensible to many. Finally, even within North America, we also must use caution in applying normative data from the SIPT, as the norms are quite old and may no longer reflect child performance accurately.

Almost two decades have passed since we published the second edition of *Sensory Integration: Theory and Practice* (Bundy, Lane, & Murray, 2002). Evaluation of some aspects of SI without the SIPT has gotten easier in that time because of new assessments. These include the family of tools that comprise the *Sensory Profile-2* (SP2; Dunn, 2014) and the *Sensory Processing Measure* (SPM; Parham, Ecker, Kuhaneck, Henry, & Glennon, 2010). These parent- and teacher-report assessments address sensory processing and modulation, body awareness and praxis, and the functional sequelae of difficulties with each. Because the cost to administer these tools is less prohibitive than for the SIPT, many therapists seem to have adopted parent- and teacher-report measures in lieu of the favored SIPT. However, sensory items from the SP2 and the SPM are organized by system rather than in a way that makes it easy to distinguish difficulties with modulation, sensory discrimination, and praxis. Therefore, examiners must take particular care when interpreting findings. Similar to the SIPT, the norms from both reflect primarily the performance of children from North America, meaning that examiners also must be aware of potential cultural differences. Finally, the results of proxy-reporting are likely to be different from those derived through observation (Lane, Reynolds, & Dumenci, 2012).

Even in the absence of standardized test scores that are readily available and easily interpretable, therapists often wish to feel assured whether sensory integrative dysfunction is a factor in a child's difficulties and, if so, the nature of the dysfunction. In this chapter, we return to the heart of the model of SI presented in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) to suggest ways for therapists to supplement parent- and teacher-reporting with observations. Reliable use of these observations depends on well-honed observation skills and a thorough understanding of normal development. Many of the observations are drawn from Clinical Observations, described in detail in Chapter 9 (Using Clinical Observations within the Evaluation Process). It is also important to be reminded that assessment of the performance of everyday occupations should always accompany examination of SI. These are included, to a degree, in the SPM and SP2 tools, but we also refer readers to Law, Baum, and Dunn (2005) for a review of additional assessments.

Sensory Integration Theory Revisited

In Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited), we proposed a model of sensory integrative dysfunction comprising two major types of dysfunction: dyspraxia and poor modulation of sensation; either can have a basis in poor processing of vestibular, proprioceptive, or tactile sensations. Dyspraxia is manifest in poor bilateral integration and sequencing or somatodyspraxia. Modulation problems can be seen as over-responsivity (i.e., defensiveness or aversive responses), under-responsivity, or fluctuating responsivity (see Fig. 1-6). If the theory of SI is sound, then the results of any valid, reliable measures of the constructs described (e.g., posture, tactile discrimination, bilateral integration) should provide information about one or more aspects of sensory integrative functioning. Of course, assessments are valid and reliable only within their intrinsic limitations. Information related to assessment reliability and validity is generally available in test manuals and in reports of research examining the test's measurement properties.

To say that individuals have sensory integrative dysfunction, we must find **meaningful clusters** that relate a particular problem with motor coordination, attention, or behavior to poor processing of sensation. Thus, for example, it is not enough to identify a problem with bilateral coordination (e.g., difficulty manipulating paper and scissors to cut out a shape, difficulty coordinating the two sides of the body in skipping) and assume sensory integrative dysfunction. If the problem *is* sensory integrative in nature, there also will be evidence of poor processing of vestibular or proprioceptive information (e.g., low muscle tone, poor prone extension). If a problem with distractibility is an end-product of sensory integrative dysfunction, then there will be evidence of poor modulation of tactile, vestibular, or proprioceptive sensation. In Figure 10-1, we embellish the model of SI by proposing assessments that might be used to examine the constructs. Table 10-1 contains a key to the assessments appearing in Figure 10-1 as well as supplementary detail.

CASE STUDY ▪ LENARD

Lenard, age 6, is a quiet child; he gets along with most of his peers and relates well to the caregivers at preschool. He seems a bit immature for his age in terms of the play activities in which he engages. Lenard attained his milestones generally on time, although most at the later end of typical development. He was quite content to sit and play quietly at home, exploring his environment minimally. His mother enrolled him in preschool at age 3, hoping his motor and interaction skills would improve by being around peers. Generally, Lenard seems clumsy with movement; he runs rarely and often trips over the legs of chairs and other

TABLE 10-1 Tests for Identifying Aspects of Sensory Integrative Dysfunction in the Absence of the SIPT

TEST		CONTRIBUTOR TO SI ASSESSMENT	MOD	POSTURE	SOMATO DISCRIM	VBIS	SD
BOT2	Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.) • Bruininks and Bruininks, 2013	• Strength and Agility • Body Coordination • Manual Coordination • Fine Manual Control		✓		(✓) ✓ ✓	(✓) ✓ ✓ ✓
MABC-2	Movement ABC-2 • Henderson, Sugden, and Barnett, 2007	• Static and Dynamic Balance • Ball Skills • Manual Dexterity		✓		 ✓	 ✓ ✓
MABC Checklist	MABC Checklist • Henderson and Sugden, 1992	Parent perceptions of child motor skills				✓	✓
NIH Toolbox	NIH Toolbox Somatosensory Items	Somatosensory discrimination			✓		
M-FUN	Miller Function and Participation Scales	• Gross motor • Fine motor • Visual motor		✓			
SPM	Sensory Processing Measure • Parham, Ecker, Kuhaneck, Henry, and Glennon, 2010	• Vision • Hearing • Touch • Taste and Smell • Body Awareness • Balance and Motion • Planning and Ideas	✓ ✓ ✓ ✓ ✓ ✓	(✓) (✓)	 ✓ (✓)	 (✓) (✓)	 (✓) (✓)

Continued

TABLE 10-1 Tests for Identifying Aspects of Sensory Integrative Dysfunction in the Absence of the SIPT—cont'd

TEST		CONTRIBUTOR TO SI ASSESSMENT	MOD	POSTURE	SOMATO DISCRIM	VBIS	SD
SP2	Sensory Profile 2 • Dunn, 2014	• Seeking/Seeker	✓				
		• Avoiding/Avoider	✓				
		• Sensitivity/Sensor	✓				
		• Registration/Bystander	✓				
		Measures senses separately; posture and movement items interspersed		(✓)		(✓)	(✓)
SP (AA)	Adolescent/Adult Sensory Profile • Brown and Dunn, 2002	• Poor registration	✓				
		• Sensitivity to stimuli	✓				
		• Sensation seeking	✓				
		• Sensation avoiding	✓				
COs	Clinical Observations • Chapter 9, Using Clinical Observations within the Evaluation Process	• Prone extension	✓				
		• Postural reactions	✓				
		• Extensor tone	✓				
		• Head and neck in supine	✓				
		• Supine flexion	✓				✓
		• Dynamic reach (kneel)	✓				
		• RAMP movements					✓
		• Ball play				✓	
		• Jumping jacks/stride jumps				✓	
COMPS	Clinical Observations of Motor and Postural Skills	• Slow movements	✓			✓	
		• Diadokokinesia				✓	
		• Finger-nose touching				✓	
		• Prone extension	✓			✓	
		• Supine flexion	✓				
		• Asymmetrical tonic neck reflex					
SCSIT (SD)	Southern California Sensory Integration Tests of Sensory Discrimination • Ayres, 1980	• Localization of tactile stimuli			✓		
		• Finger identification			✓		
		• Graphesthesia			✓		
		• Manual form perception			✓		
		• Kinesthesia[1]			✓		

[1]Conceptually, the Kinesthesia test reflects somatosensory discrimination, which Ayres felt was an important contributor to body scheme. However, the reliability of this test is quite low. Thus, it should not be used as a sole indicator and it should be used with caution.

things left on the floor. He does not enjoy climbing, and he will not jump off things such as curbs. He can manage a spoon and fork for eating, but he has difficulty using scissors and writing his name. As he is preparing to enter kindergarten, both the preschool caregivers and his parents have concerns.

Lenard's behavior at home is not a problem (he is an only child); in preschool, he has had difficulty sharing toys and space as well as cooperating with other children during free play. Lenard shows a preference for playing with a single peer at a time, seeming to become anxious when others join in. Not understanding the rules at school about sharing and including interested friends, when the group becomes too large, Lenard moves away and finds something else to play. He does well interacting with the caregivers at preschool, and often they can help him play with others, especially if the games and play themes are familiar to him. Lenard repeats common play themes and activities and seems lost when other children or adults suggest changing the game. For instance, he

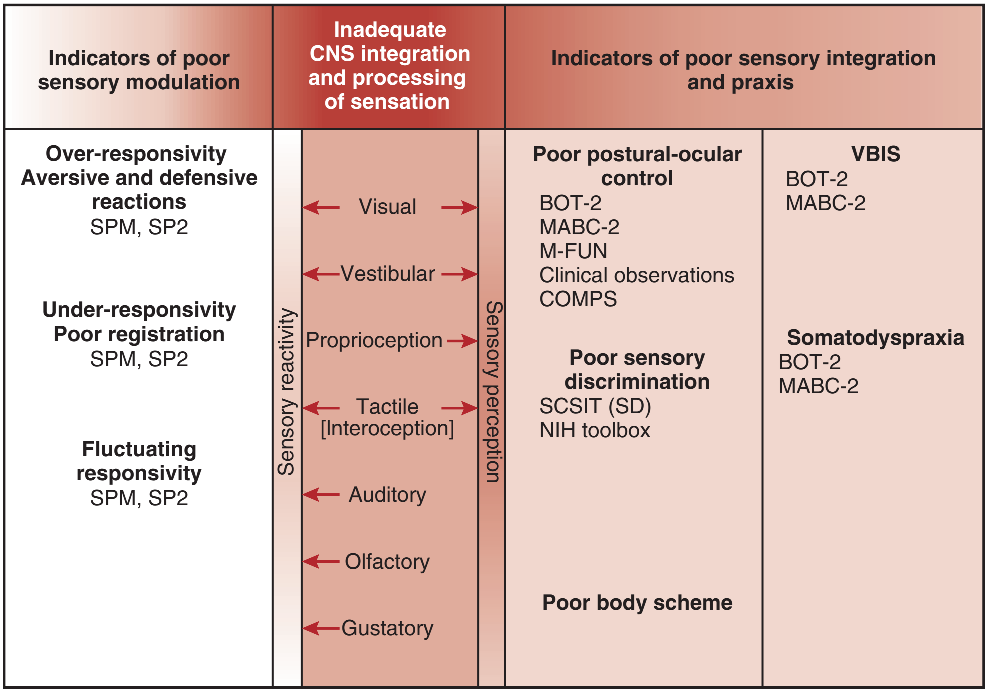

FIGURE 10-1 Relationship of tests to sensory integration theory.

likes to build trucks with blocks, but he always builds a fire truck and likes to put out pretend fires. When other boys wanted to change to dump trucks and play a construction game, Lenard seemed lost and uncertain how to make it fun. Rather than join in with this game, Lenard stood back and watched them play.

Dyspraxia

In the evaluation of dyspraxia, we rely most heavily on two assessments: the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT2) and the Movement Assessment Battery for Children-2 (MABC-2), which includes both a performance test and an accompanying **proxy-report** checklist. The BOT2 comprises four motor composites, each of which includes subtests. Many of these provide normative data for observations that therapists make as structured or unstructured observations in the context of assessment of SI dysfunction. Hypothesized relationships between BOT2 subtests and SI dysfunction are shown in Table 10-1 and Figure 10-1. The BOT2 yields standard scores for children, adolescents, and young adults from 4 through 21 years of age. The test manual (Bruininks & Bruininks, 2013) and authors of a review article (Deitz, Kartin, & Kopp, 2007) provide reasonable evidence for reliability and validity of data gathered with the BOT2. However, Deitz and colleagues noted that not all subtests are reliable at all ages and that very young children (4- and 5-year-olds), especially those with motor delays, find some items very challenging.

Based on research with predecessors to both the BOT2 (i.e., the Bruininks-Oseretsky Test of Motor Performance [BOTMP], Bruininks, 1978) and the SIPT (i.e., the Southern California Sensory Integration Tests [SCSIT]; Ayres, 1980), there is some support for including the BOT2 in an evaluation of praxis. Relating composite or total (fine motor composite, gross motor composite, total composite) BOTMP scores with individual tests from the SCSIT, Ziviani and colleagues (1982) found several statistically significant ($p < 0.01$) correlations between SCSIT scores and BOTMP fine, gross, and battery composites. Further, Wilson and colleagues (1995) found that four BOTMP subtests were particularly good for identifying children with mild motor difficulties:

- Running Speed and Agility
- Balance
- Visual-Motor Coordination
- Upper Limb Speed and Dexterity

However, it is important to note that the BOT2 is a substantially different test from the BOTMP, and more work will need to be done to establish it as a proxy for evaluating praxis (Bruininks & Bruininks, 2013; Deitz, Kartin, & Kopp, 2007).

The MABC (Henderson & Sugden, 1992), predecessor to the Movement ABC-2, was standardized on children in the United States, Canada, and the United Kingdom (UK). Some researchers (Rosblad & Gard, 1998; Smits-Engelsman, Henderson, & Michels, 1998) have found **generalizability** of the norms adequate in Europe, but others (Livesey, Coleman, & Piek, 2007) have suggested there are cultural differences in Australia and, possibly, in Asia. The Performance Test of the MABC-2 includes items designed to assess manual dexterity, ball skills, and balance. Similar to the BOT-2, many MABC-2 items provide normative data for observations that therapists would make as structured or unstructured observations in the context of assessment of sensory integrative dysfunction. Hypothesized relationships between MABC-2 subtests and sensory integrative dysfunction are shown in Table 10-1 and Figure 10-1.

The MABC-2 yields standard scores for children and adolescents from 3 through 16 years of age. However, in a review article, Brown and Lalor (2009) pointed out that, although a fair amount of research has addressed the psychometric properties of the MABC, there is very little evidence for reliability or validity of data gathered with the MABC-2. Brown and Lalor reminded us that there are substantial differences between the MABC and the MABC-2. Thus, normative data drawn from the MABC-2, although likely better than most examiners' knowledge of how well children at varying ages should perform, still should be used cautiously. In the case at the end of this chapter about Lenard, the MABC-2 has been used in this manner.

The checklist included in the MABC-2 yields ratings from parents on a variety of everyday activities. In developing this checklist, Henderson and Sugden (1992) applied the hierarchy of difficulty of movement tasks described by Gentile and colleagues (1975) and Keogh and Sugden (1985). This hierarchy is based on both the amount of movement of a target object and the amount of movement required of the individual to act on the object, and that hierarchy reflects the construct of praxis as a continuum (see Chapter 5, Praxis and Dyspraxia, for more detailed discussion of praxis). For instance, donning a shoe while sitting on the floor involves little movement of the target (shoe) and little movement of the individual to act on the target. In contrast, donning the shoe while standing up may involve a great deal of movement of both the target (shoe) and individual if the person is hopping about trying to put the shoe on! Therefore, information on the potential impact of problems with praxis on a child's ability to perform many activities of daily living may be derived from interpretations made from the scores on the MABC-2 Checklist.

An older tool that therapists may use to gain insight into motor coordination is the Clinical Observations of Motor and Postural Skills-Second Edition (COMPS-2; Wilson, Pollock, Kaplan, & Law, 2000). The COMPS-2 is a standardized and norm-referenced screening tool for children from 5 to 15 years of age, and it reflects a refinement of Ayres' Clinical Observation (Ayres, 1976), based on the items that could be reliably administered and scored. It is intended to be a useful supplement to standardized testing. Items on the COMPS-2 include **slow movements,** diadokokinesia, finger-nose touching, prone extension, supine flexion, and the asymmetrical tonic neck reflex. No research could be found on this second edition, but good 2-week test–retest and inter-rater reliability and **internal consistency** were noted in the first edition when testing children with and without developmental coordination disorder (Wilson, Pollock, Kaplan, Law, & Faris, 1992). Changes to the second edition involved expanding the age range from 5 years of age and 9 years 11 months of age, to 5 years of age and 15 years of age; as such, applying these psychometrics to testing older children must be done cautiously.

Other tools are available to assess gross and fine motor function. For instance, the Miller Function & Participation Scales (M-FUN; Miller, 2006) has assessment items for gross, fine, and visual motor performance and ties motor performance to participation. The usefulness of tools, such as the M-FUN, for assessing aspects of sensory integrative function comes from using observational skills to examine the *quality* of motor performance, giving thought to how each task was conceptualized, planned, and executed. As such, the M-FUN and other similar tools can offer insights into end products commonly associated with SI dysfunction (fine, gross, and visual motor, and participation) but, alone, do not allow us to conclude that sensory integrative concerns are at the root of any problem.

CASE STUDY ▪ LOOKING AT LENARD'S PRAXIS

Lenard was referred for an occupational therapy evaluation to investigate his motor skills and clumsiness, hesitancy to play in groups, and preference for sameness in play. Our background in SI theory guides us in the evaluation process, but we decided not to use the SIPT. Instead, we used a combination of assessments to address the concerns. In considering his motor skills, we recognized that Lenard appears clumsy, leading us to be concerned about vestibular and proprioceptive processing, postural-ocular control, and praxis. We decided to use the MABC-2, the checklist for the MABC, and Clinical Observations to examine these areas. Results from the MABC-2 indicated that Lenard had difficulty with static and dynamic balance and ball skills, with percentile ranks of 3 for balance and 5 for ball skills. His manual dexterity percentile was 7, indicating borderline performance. The checklist, completed by his mother, put him clearly in the red zone. Also, Lenard was identified by his mother as being somewhat timid and anxious, which could influence his movement scores.

On the model shown in Figure 10-2, we have "plotted" our interpretations of these findings and show a "plus" (+) for areas of concern and a "minus" (–) for areas where we do not have concern. You can see that we have hypothesized that Lenard's MABC-2 suggests difficulty with postural-ocular control and implicates difficulty with vestibular and proprioceptive processing.

HERE'S THE POINT

- Sometimes it is impractical and not feasible or necessary to administer the SIPT.
- Clinical Observations, and the administration of other assessments, such as the SP2, SPM, BOT2, MABC-2, the COMPS, and the M-FUN, may be used to gather important information about a child's praxis abilities and how dyspraxia may be impacting a child's ability to perform his or her daily occupations.

Assessment of Somatosensory Discrimination

Few standardized tests of somatosensory discrimination exist. If they are available, several tests from the SCSIT (Ayres, 1980), which have published norms for children between 4 and 9 years of age, offer a structure to observing discrimination that may be useful. Similar to the SIPT, these tests examined stereognosis, localization of touch, finger identification, graphesthesia, visual-tactile integration, and kinesthesia. Caution is needed, however; these tactile tests are known to ceiling early, several are associated with large errors and relatively poor test–retest reliability, and the SCSIT was standardized more than 40 years ago. They are no longer available commercially. Because of these shortcomings, readers are urged not to report standard scores in documentation. Rather, consider scores above 1 standard deviation below the mean (> –1.0) to reflect typical functioning, and scores below that to be indicative of performance markedly below that of most children of a given age. These tests become a way to structure observation of performance and provide guidelines for interpretation if used cautiously.

Recently, the National Institutes of Health (NIH) developed a Toolbox of assessments designed to be short, simple, and usable across the life span (Gershon et al., 2013). The whole Toolbox includes assessments of cognition, emotion, motor, and sensory functions; individual items may be useful for individuals from 3 to 85 years of age with a variety of adaptations based on age. Measures of sensation include auditory **"word-in-noise,"** visual acuity, odor identification, taste perception, and pain scales for

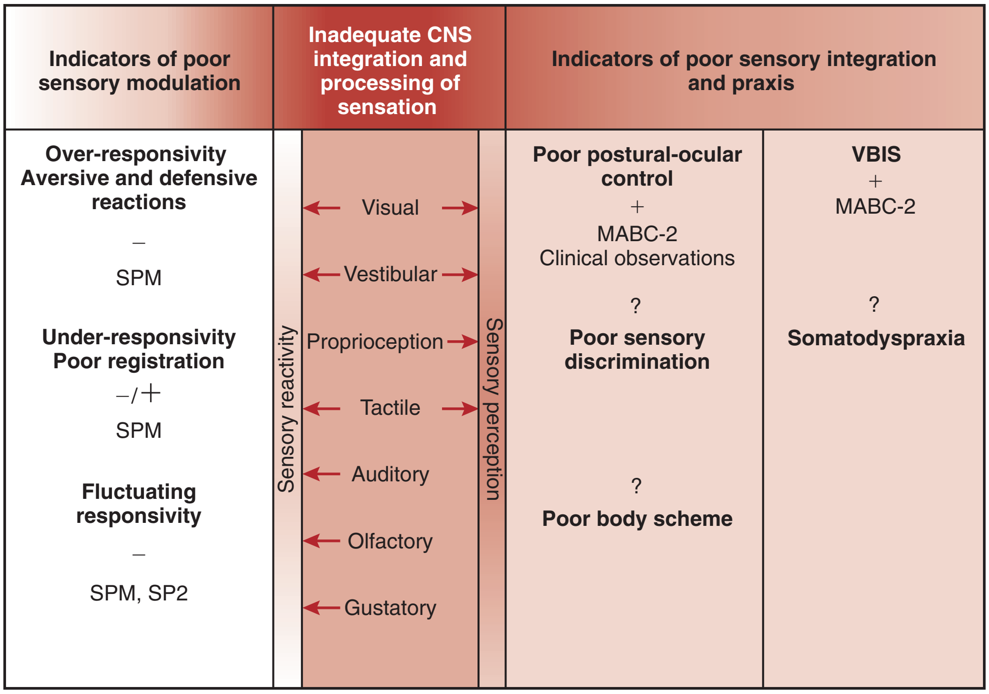

FIGURE 10-2 Categorizing Lenard's performance on assessments.

adults (http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox/intro-to-nih-toolbox/sensation). Although these sensory items are not intended to provide detailed information on sensory discrimination, they may be useful as a screening tool. For instance, the NIH Toolbox items related to somatosensory discrimination include the *Brief Kinesthesia Test,* based on the Kinesthesia test of the SCSIT and the SIPT; a *Wrist Position Sense Test,* a Tactile Discrimination Test based on texture discrimination; a localization of touch tool using Semmes-Weinstein monofilaments; and a *Brief Manual Form Perception Test,* based on the manual form subtests of the SCSIT and the SIPT (Dunn et al., 2015). Performance ranges are offered based on initial life-span testing. The Toolbox sensory items offer an accessible, quick, and inexpensive means of screening people for sensory and proprioceptive perception.

HERE'S THE POINT

- There is no single, standardized assessment of children's sensory discrimination abilities.
- Use of the somatosensory subtests from the SCSIT may provide guidance for understanding tactile and proprioceptive processing in children.
- The NIH Toolbox somatosensory items provide a useful screening tool for these functions in children.

Assessment of Postural and Ocular Control

Postural and ocular control are thought to be important outward indicators of vestibular-proprioceptive perception. To assess them, we include:

- The balance subtest from the BOT2 and items from the MABC-2
- Other standard Clinical Observations of neuromotor performance (see the previous information on the COMPS and Chapter 9, Using Clinical Observations within the Evaluation Process, for more information on assessing Clinical Observations)

Standard Clinical Observations are very useful when assessing SI, with or without the SIPT.

We have used Clinical Observations in trying to tease out Lenard's strengths and needs in the case that is in this chapter. Blanche, Bodison, Chang, and Reinoso (2012) described, and provided preliminary normative data for, several Clinical Observations in Chapter 9 (Using Clinical Observations within the Evaluation Process). The following provide information about vestibular-proprioception:

- Prone extension
- The head and neck component of supine flexion
- Postural reactions in standing
- Dynamic reach in tall kneeling

Blanche and colleagues also provided guidelines and preliminary normative information for assessing the following bilateral- and praxis-related tasks:

- Supine flexion
- Feedback-dependent tasks (i.e., slow RAMP movements)
- Feedforward-dependent tasks (i.e., ball play)
- Sequencing tasks (i.e., rapidly alternating movements; sequential finger touching)
- Skipping
- Jumping jacks and stride jumps

CASE STUDY ■ LENARD'S CLINICAL OBSERVATIONS PERFORMANCE

Lenard seemed very interested in engaging in the Clinical Observations, but he found them challenging. We observed that Lenard had difficulty assuming and maintaining prone extension and showed poor postural reactions and difficulty reaching while maintaining his posture on a mobile surface. He could neither do jumping jacks nor skip. We added Clinical Observations to the model in Figure 10-2, supporting the interpretation we had made based on the MABC-2.

HERE'S THE POINT

- Assessment of postural and ocular control relies on Clinical Observations.

A Need for Caution and Clinical Reasoning in Testing without the SIPT

Although the suggested tools may provide the basis for assessment in situations where the SIPT are impractical or impossible, there are several limitations inherent to their use, particularly with regard to praxis. First, they frequently use items, tests, or subtests excerpted from a total test battery. This most certainly affects the reliability and, thus, the validity of the items. Second, terminology may be a problem. The proposed alternative testing was developed from knowledge of SI dysfunction blended with an analysis of demands of test items. In considering the application of alternative tools to understand SI function and dysfunction, one must rely heavily on this acquired knowledge and the clinical reasoning process. Schaaf and Mailloux (2015) delineate one clinical reasoning process that may be useful, and they operationalize it with a child with autism (Faller, van Hooydonk, Mailloux, & Schaaf, 2015). Although the names of subtests or tests, especially those associated with the MABC-2, may appear to reflect one construct of SI, analysis sometimes suggested that an item was a better measure of a different construct. In some cases, items within subtests appear to reflect different constructs.

Third, both the BOT2 and the MABC-2 performance tests are thought to be tests of motor abilities (Burton & Miller, 1998). Burton and Miller argued that abilities inferred from tests such as the BOT2 may be skill-specific rather than reflecting general underlying capacities. Burton and Miller believed that a far preferable method for evaluating performance was to assess functional movement skills (i.e., those done within the context of everyday activity). Of the tests described in this chapter, the MABC Checklist and the Participation Assessment of the M-FUN are the only assessments that fall fully in that category. Finally, an accurate assessment of praxis is dependent on valid testing of sensory discrimination. Unfortunately, few tools that are standardized and psychometrically sound exist for assessment of these functions; the SCSIT subtests may not be readily available and have inherent weaknesses, and the NIH Toolbox sensory items serve more as a screening than an assessment. Thus, results of the tests proposed must be used cautiously.

Assessment of Sensory Modulation Disorders

SI theory describes two broad categories of disorders manifested as (1) dyspraxia and (2) poor modulation (see Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited). The SIPT yield scores reflecting only praxis and the sensory discrimination abilities thought to underlie it. Thus, a complete assessment of SI must include measures beyond the SIPT. For an evaluation of modulation disorders, we cite two "families" of tests: (1) SPM (Parham, Ecker, Kuhaneck, Henry, & Glennon, 2010); and (2) the SP2 (Dunn, 2014), with versions for infants, toddlers, and children, and the Adolescent/Adult SP (Brown & Dunn, 2002). These tests provide a formal means for assessing modulation and are used commonly in practice. However, none is purely a test of modulation; all are tests of sensory processing, the umbrella construct encompassing both modulation and discrimination. The "umbrella" and components of modulation and discrimination are depicted in the model in Figure 10-1. In the center is SI and processing; moving to the left, we find sensory reactivity or modulation constructs, and moving to the right are constructs that encompass sensory discrimination. Further, items from the SPM in particular, identify difficulties with participation at home, in school, and in the community that are thought to stem from poor sensory processing. Thus, when therapists seek specific information about sensory modulation, they must choose specific test sections carefully and then carefully evaluate the items in each.

Sensory Processing Measure (SPM)

The SPM and the SPM-P, rooted in SI theory, can be used with children from 2 to 12 years of age. These tools have excellent evidence for test–retest and other aspects of reliability as well as multiple aspects of validity. See Chapter 16 (Advances in Sensory Integration Research: Basic Science Research) and the test manuals (Parham, Ecker, Kuhaneck, Henry, & Glennon, 2010) for more details on psychometric properties.

Sensory Profile-2 (SP2)

The SP2 (Dunn, 2014) and the Adolescent/Adult SP (Brown & Dunn, 2002) are useful with individuals from infancy through 65+ years of age. This family of tests has evidence for good to excellent test–retest and inter-rater reliability and has been found to differentiate successfully between children who are developing typically and children with a range of developmental conditions, including developmental delay, attention deficit-hyperactivity disorder, autism, learning disabilities, intellectual disability, and others, although the research involved relatively small samples. The authors have correlated SP2 scores with scores on tests that have overlapping constructs (e.g., Behavior Assessment System for Children; Social Skills Inventory System; Vineland, School Function Assessment). See Chapter 16 (Advances in Sensory Integration Research: Basic Science Research) and the test manuals (Dunn, 2014; Brown & Dunn, 2002) for more details on psychometric properties.

The SP2 tests are based in a conceptual model of sensory modulation comprising two continua: (1) neurological thresholds (low to high) and (2) mechanisms for self-regulation (active to passive) (see Fig. 10-3). Scores can be interpreted such that individuals' responses are described by one of four sensory processing patterns. Categories that occupy the upper half of the framework describe individuals with relatively high sensory thresholds. Individuals represented in the upper left of the diagram respond passively to high neurological thresholds; Dunn referred to them as "bystanders." Individuals whose behavioral responses place them in this category may miss sensory cues that others notice easily. In contrast, Dunn referred to individuals who actively self-regulate a high threshold (upper right) as "seekers." She felt they attempted to counteract a high threshold (and boredom) by creating sensory rich environments. Dunn described individuals represented in the categories that occupy the lower half of the framework as having lowered sensory thresholds. She labeled individuals who respond passively to lowered thresholds (lower left) as "sensors"; they respond

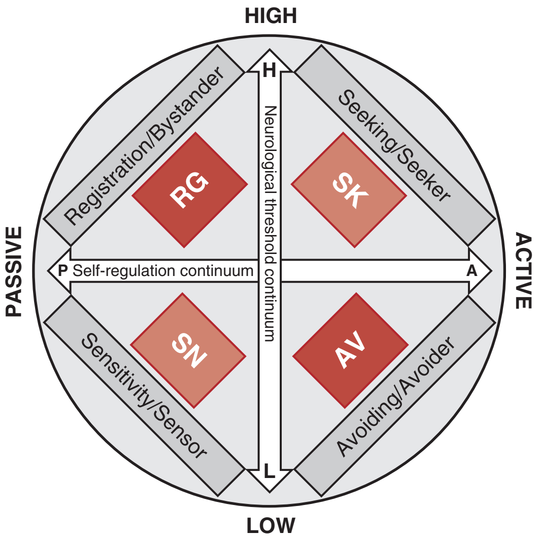

FIGURE 10-3 Dunn's model of neurological threshold and self-regulation. Dunn's model reflects an interface between the neurological threshold continuum (vertical white arrow) and the self-regulation continuum (horizontal white arrow). Individuals with a high neurological threshold will be considered "bystanders" if their approach to self-regulation is passive but "seekers" if their approach to self-regulation is active. Similarly, those with a low neurological threshold will be considered "sensors" if they assume a passive self-regulation approach but "avoiders" if they are active in their approach to self-regulation. *Sensory Profile 2. Copyright © 2014 NCS Pearson, Inc. Reproduced with permission. All rights reserved.*

readily to sensory stimuli, noticing things other people often fail to notice. Finally, Dunn referred to individuals represented in the lower right as "avoiders." They actively self-regulate lowered thresholds by withdrawing from, or blocking, sensation and structuring their routines and the environment (see Figure 10-3).

CASE STUDY ▪ LENARD'S SENSORY MODULATION AND OUR CONCLUSIONS

In addition to examining praxis and postural control, we were concerned that Lenard might have a sensory modulation disorder that interfered with him wanting to play in groups of children; perhaps it is the closeness of others that bothers him when he is in a group. For this, we decided to ask both parent and teacher to complete the SPM forms. We also administered measures of childhood anxiety and self-efficacy, but we will not address those here.

On the SPM, there were some differences between perspectives of his teacher and his mother, but, overall, Lenard fell within a typical range in the areas of hearing, touch, taste, and smell. He had some difficulty on items reflecting body awareness, balance and motion, and planning and ideation. On the model (Fig. 10-2), we show a +/– for "under-responsivity/poor registration" as this seems to go with what both his parents and teacher reported relative to body awareness, balance and motion, and planning and ideation. We did not find sufficient reason to consider sensory over-responsivity or fluctuating responsiveness, as can be seen in Figure 10-2. We did not assess somatosensory discrimination, so we cannot address this area.

Based on this collection of findings, we hypothesized that Lenard's difficulties are mostly related to inadequate vestibular and proprioceptive processing, reflected as poor postural control and difficulty with bilateral movements. His hesitancy to play with a group did not seem related to sensory over-responsivity but, instead, may be related to clumsy movements and possibly some under-responsivity. We tentatively related his hesitancy to engage in new and unfamiliar play themes and games to difficulties with planning and ideation and, possibly, poor postural and bilateral skills. However, we made these links very cautiously as our assessment did not directly address some of these areas. We recommended that Lenard receive intervention, and we will engage in ongoing assessment as we work with Lenard to confirm or reject our hypotheses, and to help us better understand Lenard's strengths and needs.

HERE'S THE POINT

- Sensory modulation is an important aspect of SI functioning that is not captured through the administration of the SIPT.
- The SPM and SP2 are two families of tools with adequate psychometric properties that can be used to assist clinicians in assessing sensory processing and modulation functions.

HERE'S THE EVIDENCE

Su and Parham (2014), in their article titled "Validity of Sensory Systems as Distinct Constructs," reported research that supports the idea that tactile, vestibular–proprioceptive, visual, and auditory systems form distinct, valid factors that are not age-dependent. Therefore, assessment tools yielding scores based on sensory systems (such as the SPM) provide a valid approach to clinical assessment. The results of this study suggest that a specific sensory system found to be vulnerable or not functioning well may present with a variety of difficulties at different times, such as over- and under-reactivity, as well as result in perceptual and motor problems. Therefore, when assessment findings suggest problems within a particular sensory system, clinicians need to probe further by analyzing the responses to specific test items within that system. This helps to determine the types of sensory processing problems that occur within the specific sensory system as well as how the sensory processing or modulation differences manifest throughout the child's activities and within the routines of daily life.

Summary and Conclusions

Using the SIPT can be expensive and time-consuming, the applicability of the norms to populations outside of North America is largely unknown, and the norms are dated. Further, by themselves, the SIPT do not provide a complete assessment of SI functioning. Nonetheless, to date, they remain the most comprehensive and psychometrically sound set of tests for assessing praxis and the sensory discrimination functions thought to underlie it. When examiners embark upon assessment without the SIPT, they must be prepared to carefully select and interpret the results of testing drawn from several sources. This requires thorough knowledge of SI theory, significant clinical reasoning, and a substantial investment of time and energy in processes different from those associated with administration and interpretation of SIPT scores. We have offered some guidelines to assist with the process, but the bulk of the work remains with the examiner.

Where Can I Find More?

An article by Mailloux, Parham, Roley, Ruzzano, and Schaaf (2018) introduces the new Evaluation in Ayres Sensory Integration® (EASI) tests. EASI authors seek to make it an inexpensive, electronically accessible, practical, valid, and reliable instrument for evaluating children between 3 and 12 years from many nations of the world. EASI tests represent four categories: Sensory Perception; Praxis; Postural/Ocular/Bilateral Motor Integration; and Sensory Reactivity. Readers can follow the multi-stage development process for the EASI at https://sites.google.com/site/2020asivision/home/goal-2-international-test.

References

Ayres, A. J. (1976). *Interpreting the Southern California Sensory Integration Tests*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1980). *Southern California Sensory Integration Tests manual: Revised 1980*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual*. Los Angeles, CA: Western Psychological Services.

Blanche, E. I., Bodison, S., Chang, M. C., & Reinoso, G. (2012). Development of the comprehensive observations of proprioception (COP): Validity, reliability, and factor analysis. *American Journal of Occupational Therapy, 66*(6), 691–698. doi:10.5014/ajot.2012.003608

Brown, C., & Dunn, W. (2002). *Adolescent/Adult Sensory Profile*. San Antonio, TX: Pearson.

Brown, T., & Lalor, A. (2009). The Movement Assessment Battery for Children—Second Edition (MABC-2): A review and critique. *Physical & Occupational Therapy in Pediatrics, 29,* 86–103.

Bruininks, R. H. (1978). *Bruininks-Oseretsky Test of Motor Proficiency manual*. Circle Pines, MN: American Guidance Services.

Bruininks, R. H., & Bruininks, B. D. (2013). *Bruininks-Oseretsky Test of Motor Proficiency manual, second edition*. San Antonio, TX: Pearson.

Bundy, A. C., Lane, S. J., & Murray, E. A. (2002). *Sensory integration: Theory and practice* (2nd ed.). Philadelphia, PA: F. A. Davis.

Burton, A. W., & Miller, D. E. (1998). *Movement skill assessment*. Champaign, IL: Human Kinetics.

Deitz, J. C., Kartin, D., & Kopp, K. (2007). Review of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). *Physical and Occupational Therapy in Pediatrics, 27,* 87–102.

Dunn, W. (2014). *Sensory Profile2: User's manual*. San Antonio, TX: Psychological Corporation.

Dunn, W., Griffith, J. W., Sabata, D., Morrison, M. T., MacDermid, J. C., Darragh, A., . . . Tanquary, J. (2015). Measuring change in somatosensation across the lifespan. *American Journal of Occupational Therapy, 69,* 6903290020. doi:10.5014/ajot.2015.014845

Faller, P., van Hooydonk, E., Mailloux, Z., & Schaaf, R. (2015). Application of data-driven decision making using Ayres Sensory Integration® with a child with autism. *American Journal of Occupational Therapy, 70*(1), 7001220020p1-7001220020p9. doi:10.5014/ajot.2016.016881

Gentile, A. M., Higgins, J. R., Miller, E. A., & Rosen, B. M. (1975). The structure of motor tasks. *Movement, 7,* 11–28.

Gershon, R. C., Wagster, M. V., Hendrie, H. C., Fox, N. A., Cook, K. F., & Nowinski, C. J. (2013). NIH toolbox for assessment of neurological and behavioral function. *Neurology, 80*(11 Suppl 3), S2–S6. doi:10.1212/WNL.0b013e3182872e5f

Henderson, S. E., & Sugden, D. A. (1992). *Movement Assessment Battery for Children manual*. New York, NY: Psychological Corporation.

Henderson, S. E., Sugden, D. A., & Barnett, A. (2007). *Movement Assessment Battery for Children-2 manual*. San Antonio, TX: Pearson.

Keogh, J. F., & Sugden, D. A. (1985). *Movement skill development*. New York, NY: MacMillan.

Lane, S. J., Reynolds, S., & Dumenci, L. (2012). Sensory overresponsivity and anxiety in typically developing children and children with autism and attention deficit hyperactivity disorder: Cause or coexistence? *American Journal of Occupational Therapy, 66*(5), 595–603. doi:10.5014/ajot.2012.004523

Law, M., Baum, C., & Dunn, W. (2005). *Measuring occupational therapy performance: Supporting best practice in occupational therapy* (2nd ed.). Thorofare, NJ: Slack Inc.

Livesey, D., Coleman, R., & Piek, J. (2007). Performance on the Movement Assessment Battery for Children by Australian 3- to 5-year-old children. *Child: Care, Health and Development, 33*(6), 713–719.

Mailloux, Z., Parham, L. D., Roley, S. S., Ruzzano, R., & Schaaf, R. (2018). Introduction to the Evaluation in Ayres Sensory Integration® (EASI). *American Journal of Occupational Therapy, 72,* 7201195030p1–7201195030p7. doi:10.5014/ajot.2018.028241

Miller, L. J. (2006). *Miller Function & Participation Scales manual*. San Antonio, TX: Harcourt Assessment.

Parham, L. D., Ecker, C., Kuhaneck, H. M., Henry, D. A., & Glennon, T. J. (2010). *Sensory Processing Measure: Manual*. Los Angeles, CA: Western Psychological Services.

Rosblad, B., & Gard, L. (1998). The assessment of children with developmental coordination disorders in Sweden: A preliminary investigation of the suitability of the movement ABC. *Human Movement Science, 17,* 711–719.

Schaaf, R. C., & Mailloux, Z. (2015). *A clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism*. Bethesda, MD: AOTA Press.

Smits-Engelsman, B. C. M., Henderson, S. E., & Michels, C. G. J. (1998). The assessment of children with developmental coordination disorders in the Netherlands: The relationship between the movement assessment battery for children and the Korperkoordinations Test fur Kinder. *Human Movement Science, 17,* 699–709.

Su, C.-T., & Parham, L. D. (2014). Validity of sensory systems as distinct constructs. *American Journal of Occupational Therapy, 68,* 546–554. doi:10.5014/ajot.2014.012518

Wilson, B., Pollock, N., Kaplan, B. J., Law, M., & Faris, P. (1992). Reliability and construct validity of the Clinical Observations of Motor and Postural Skills. *American Journal of Occupational Therapy, 46*(9), 775–783.

Wilson, B. N., Polatajko, H., Kaplan, B. J., & Faris, P. (1995). Use of the Bruininks-Oseretsky Test of Motor Proficiency in occupational therapy. *American Journal of Occupational Therapy, 49,* 8–17.

Wilson, B., Pollock, N., Kaplan, B. J., & Law, M. (2000). *Clinical Observations of Motor and Postural Skills-Second Edition*. Framingham, MA: Therapro.

Ziviani, J., Poulsen, A., & O'Brien, A. (1982). Correlation of the Bruininks-Oseretsky Test of Motor Proficiency with the Southern California SI Tests. *American Journal of Occupational Therapy, 36,* 519–523.

CHAPTER

11

Interpreting and Explaining Evaluation Data

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Everything that can be counted does not necessarily count;
everything that counts cannot necessarily be counted.

—Albert Einstein

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Identify and define sensory integrative concerns based on parent interview and evaluation findings.
- ✔ Discuss the way in which sensory integration (SI) functions, including praxis affect performance and participation.
- ✔ Describe the major findings from validity studies that led to identification of patterns in SI and praxis functions.
- ✔ Identify strategies for communicating assessment findings including goal setting and report writing.

Purpose and Scope

Descriptions of the evaluation of sensory integration (SI), including the Sensory Integration and Praxis Tests (SIPT) (Ayres, 1989), related clinical observations, and measures of sensory modulation dysfunction, were presented in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests), Chapter 9 (Using Clinical Observations within the Evaluation Process), and Chapter 10 (Assessing Sensory Integrative Dysfunction without the SIPT). This chapter demonstrates how evaluation data are interpreted. We begin with a case report of Kyle, a 6½-year-old boy, recounting how we incorporated both parent report and evaluation results to determine that Kyle had sensory integrative dysfunction. We present both older and more recent research validating specific patterns of sensory integrative dysfunction and use this as a foundation for identifying the specific nature of Kyle's concerns as well as the ways in which sensory integrative dysfunction interfered with his daily life. We offer an example of how this information was shared with parents and teachers. We then provide a brief description of the evaluation process for Jackie and include our clinical reasoning in determining her strengths and needs from a sensory integrative perspective. For Jackie, we make recommendations for therapy, identify sample goals, and describe potential classroom accommodations.

Introduction

Evaluation involves gathering relevant information, and this process yields both quantitative and qualitative data. Interpretation entails making meaning from the data. When appropriate, we seek to use SI theory to explain the child's presenting problems. We use the results of the SIPT, clinical observations, and measures of sensory modulation together with relevant information obtained from the child and caregivers. We also consider additional data provided by other professionals.

Interpretation is an art that is based on a thorough understanding of the strengths and limitations of SI theory and the evaluation process. This chapter examines test scores and observations for groupings suggestive of sensory integrative dysfunction; the term *meaningful clusters* is used to explain presenting problems and as a foundation for intervention planning. If meaningful clusters cannot be identified, or when there are important presenting problems that we cannot explain, we acknowledge that SI is not the best theoretical framework for understanding the child.

Referral and Developmental History

CASE STUDY ■ KYLE

Kyle was 6½ years old when his mother, Mrs. P., initiated a referral to occupational therapy for evaluation of suspected sensory integrative dysfunction. Mrs. P.'s sister was an occupational therapist living in a different state. When Mrs. P.'s sister learned about Kyle's difficulties, she urged Mrs. P. to have him evaluated.

Kyle's mother began by saying, "I don't know what any of this means, but I want to tell you how Kyle is different from my other three children." Mrs. P. then related the story of Kyle's development from the time of his birth. We asked questions to help focus her story on relevant aspects of Kyle's childhood and the effect of his problems on his daily life. We listened carefully for evidence that an evaluation of sensory integrative functioning was warranted.

Kyle was a full-term infant, and his birth was uncomplicated. From the time of his first feeding, however, Mrs. P. felt that he was different. He was cranky and irritable, and he seemed to dislike cuddling and handling. He had difficulty nursing because of a weak suck. His sleep cycles were erratic; he did not sleep more than 4 hours until he was almost 2 years old. Even at 6 years of age, he seldom slept more than 6 hours a night.

Kyle's crankiness and difficulty sleeping were complicated by chronic ear infections. Kyle's mother had attributed all his difficult behaviors to this problem. However, even when tubes reduced the frequency of the ear infections, Kyle persisted in being somehow different from his siblings.

Although Kyle's behavior was problematic, he attained most motor milestones at the later end of "normal." He sat independently at 8 months of age and walked at 15 months of age, although he had never crawled on his hands and knees. Before he learned to walk, Kyle seemed frustrated by his inability to get around and cried a lot. Mrs. P. remembered feeling relieved when Kyle learned to walk because his disposition improved. However, her relief was short lived. The ambulatory Kyle was in constant motion. He was into everything; he fell frequently, bumped into things, and knocked things over.

Despite Kyle's difficult behaviors, Mrs. P. described him as a loving and lovable child. He was kind to his siblings, and often played well with them. He tried to help out at home although he often got distracted from his helping tasks. Although he did not like unexpected touch and hugs, he did seek hugs from Mr. and Mrs. P. Kyle often told them he loved them. He seemed bright, his language skills developed early, and he had a highly developed sense of humor.

As he grew older, Kyle's differences became more apparent. He was the second of four children. Although all the children were active, Kyle's activity often seemed without purpose. He ran from place to place and thing to thing without stopping to engage for more than a few seconds. Kyle's behavior became markedly worse when there were a lot of people or a noisy environment present. The family stopped taking him to shopping malls and avoided most restaurants. They noticed that when he ate certain foods, he became even more active, so they controlled his diet.

When Kyle was 5 years old, ready to enter kindergarten, Mrs. P. noticed that he tended to use whichever hand was closest to an object. He looked awkward when he walked and ran. He bumped into things and fell a lot. He was unable to catch or throw a ball even as well as his 3-year-old brother. He could not pump himself on a swing (although he loved to be pushed and would swing for hours). He had difficulty pedaling a small bicycle with training wheels.

Although Kyle expressed interest in coloring, artwork, and puzzles, he was not as good at them as his 4-year-old sister. Kyle often laid his upper body on the table; sometimes he fell off the chair. Whenever he got his hands even slightly dirty, he washed them immediately. Further questioning clarified that Kyle often responded adversely to light touch. Mrs. P. felt that his dislike of glue and finger paint was related to sensitivity to touch.

Mrs. P. expressed her concerns to the pediatrician when Kyle went for his kindergarten physical examination. The physician recommended trying a small dose of Ritalin. The medication seemed to help Kyle attend to tasks, and Mrs. P. believed it was beneficial. However, although he was able to focus, his activity level remained very high, he continued to be overly sensitive to touch and noise, and his coordination was not improved.

Kyle entered kindergarten at 5½ years of age. His teacher really enjoyed his sense of humor and genuinely liked him. Because she seemed to understand his needs and easily accommodated for them, Kyle's kindergarten year was a success. Mrs. P. was delighted, but she worried that he was getting further behind his peers in motor and preacademic skills and his activity level had not diminished. Although he played with his brother and sisters, he did not have any other friends.

Mrs. P. was concerned that Kyle would not succeed in first grade when he had to go to school for a whole day and the demands increased. She feared that a new teacher might not understand his needs and make the necessary adaptations. The school personnel were more optimistic and assured Mrs. P. that Kyle was bright and would do fine in first grade.

Mrs. P.'s concerns were warranted; Kyle's early days in first grade were a "disaster." He hated school. Kyle developed stomachaches and found many excuses to remain at home. His work was poor, and his behavior was worse. His teacher wrote notes indicating that he was not finishing his work, his printing was illegible, and he erased until there were holes in the paper. Sometimes he would get frustrated and tear up his papers. Kyle's teacher wondered about having him tested for special education services. At that point, Mrs. P. discussed Kyle with her sister, who recommended that an occupational therapist evaluate him.

When asked what hindered Kyle the most, Mrs. P. replied, "His poor self-esteem." She felt distractibility, clumsiness, lack of friends, and feelings that he could not do anything right contributed to his negative self-image.

The Evaluation

We scheduled an evaluation because Mrs. P.'s description suggested that sensory integrative dysfunction might be the basis for Kyle's motor difficulties, distractibility, and increased activity.

Classroom Observation

We made arrangements to observe at school and spend time with Kyle's teacher to enhance our ability to interpret test results and plan intervention. We observed during reading, arithmetic, lunch, and recess, paying careful attention to the effects of various environments on Kyle's performance.

The first grade classroom was a busy place. Kyle was one of 33 students. Because he had difficulty attending, his seat was beside the teacher's desk, and a steady stream of children passed his desk to get help or instruction. On several occasions, Kyle followed directions given to other children. Because his seat was on a major traffic route, children occasionally brushed into him. Once when this happened, Kyle hit the child and was disciplined.

Kyle's arithmetic assignment involved cutting out squares with numbers on them and pasting them on a piece of paper. Kyle's skills with the scissors, although slow and labored, were adequate. However, after he pasted the first square, he became so preoccupied with the paste on his fingers that he did not complete the assignment. Instead, he picked paste off his fingers and watched the other students.

His performance in reading group was markedly better. Kyle, his teacher, and four classmates gathered in a corner, their backs to the class. Kyle contributed to the group appropriately. However, he fell out of his chair twice and was reprimanded for his sitting posture.

At lunch, Kyle seemed completely overwhelmed by the noise and the number of children in the cafeteria. He had difficulty opening his milk container and finally used so much force that he spilled the milk. Although he sat with his classmates, he did not interact with them. Instead, he spent most of his time looking around. When lunch was finished, he had eaten only half his sandwich and one bite of fruit.

When Kyle and his classmates went outside for recess, Kyle raced around the playground, seemingly without purpose. He did not interact with any classmates or join in organized games, and none of his classmates asked him to play.

When we talked with the teacher, she indicated that the morning's activities were typical. She expressed frustration because she believed Kyle could do better if he tried harder. Her greatest concerns pertained to his behavior, especially his distractibility and activity level and not finishing his work.

Sensory Integration and Praxis Tests

The following week, we evaluated Kyle using the SIPT and the related clinical observations. Kyle's scores are shown in Table 11-1.

TABLE 11-1 Kyle's SIPT Results

TEST	SD SCORE
Space Visualization (SV)	–1.47
SV Contralateral Use	–1.05
SV Preferred Hand Use	0.62
Figure-Ground Perception	0.67
Manual Form Perception	–1.25
Kinesthesia	–0.24
Finger Identification	–0.81
Graphesthesia	–2.13
Localization of Tactile Stimuli	1.34
Praxis on Verbal Command	0.92
Design Copying	–1.69
Constructional Praxis	–2.32
Postural Praxis	–1.52
Oral Praxis	–2.72
Sequencing Praxis	–3.00*
Bilateral Motor Coordination	–2.21
Standing and Walking Balance	–2.04
Motor Accuracy	–1.42
Post-Rotary Nystagmus	–1.43

*Scores lower than –3.0 are reported by Western Psychological Services as –3.0.

Additional Testing and Observation

Kyle found it difficult to sit for prolonged periods. He particularly disliked the tactile tests and rubbed his arms and hands in response to the stimuli. He made several excuses to stop.

Kyle's mother completed the Sensory Profile-2 (SP2) (Dunn, 2014). His scores are shown in Table 11-2. Sensory section problem areas included scores in the "much more than others" category for touch and sound, reflecting over-responsivity to these sensations. His "much more than others" movement score reflected his tendency to seek movement. These findings suggested that sensory processing difficulties, particularly poor modulation in the tactile and auditory systems, interfered with daily life functioning. Modulation difficulties appeared to be affecting his activity level. He scored in the "more than others" category for conduct, social emotional responses, and attention, suggesting that poor modulation was influencing his ability to attend to relevant information in the environment, self-esteem, frustration level, social interactions, and sensitivity to criticism.

Kyle had difficulty with many clinical observations associated with vestibular and proprioceptive processing. When he tried to assume prone extension, his head was not vertical and his neck hurt; he flexed his legs sharply at the knees after only a few seconds. He maintained this approximation of prone extension for about 8 seconds.

Kyle was slightly better at performing supine flexion. He assumed the posture without assistance; however, his head lagged as he did so. He maintained supine flexion for 12 seconds. Most 6-year-old children can maintain prone extension and supine flexion for 30 seconds without excessive effort (Wilson, Pollock, Kaplan, & Law, 2000).

TABLE 11-2 Kyle's SP2 Results

	SCORE CATEGORY	RAW SCORE	INTERPRETATION
QUADRANTS	Seeking/Seeker	67	Much more than others
	Avoiding/Avoider	47	More than others
	Sensitivity/Sensor	54	Much more than others
	Registration/Bystander	25	Similar to the majority of others
SENSORY SECTIONS	Auditory	34	Much more than others
	Visual	14	Similar to the majority of others
	Touch	34	Much more than others
	Movement	33	Much more than others
	Body Position	13	Similar to the majority of others
	Oral	15	Similar to the majority of others
BEHAVIORAL SECTIONS	Conduct	30	More than others
	Social Emotional	34	More than others
	Attentional	29	More than others

Not surprisingly, Kyle also demonstrated low tone in his extensor muscles. He stood with a marked lordosis and locked knees. His proximal stability, observed in quadruped, was also poor; his scapulae winged bilaterally, and he locked his elbows and externally rotated at the shoulders to improve stability. His trunk sagged slightly. Additionally, he had difficulty modulating force in several tasks. He tended to use a great deal more force than necessary.

When seated on a large ball, he moved his trunk and limbs to prevent falling. He particularly liked this activity and asked to repeat it several times. When asked to stand on either a flat board or a tilt board and reach for an object at shoulder height, but slightly out of reach, he was able to lift one foot off the board but flexed it at the knee. When tilted on a small tilt board, he did not flex his uphill leg. Both flexing the knee while reaching and failing to bend the uphill leg when tilted are immature patterns suggesting difficulty with equilibrium (Fisher, 1989). However, overall, Kyle's equilibrium was slightly better than his ability to maintain tonic postures.

Kyle demonstrated no signs of gravitational insecurity. He enjoyed riding on moving equipment and being tipped upside down or placed in precarious positions. He also demonstrated no evidence of an aversive response to vestibular stimulation.

We observed for difficulty with bilateral coordination and projected action sequences as Kyle tried to catch a tennis ball and hop through a series of hoops. Kyle never caught the ball unless it was thrown directly into his outstretched hands. He was unable to make both feet land at precisely the same time or to execute a series of smooth jumps; he stopped after each one. His performance on jumping jacks and symmetrical and reciprocal stride jumps was poor. Also, he hesitated when crossing the midline, more with the left than the right.

We observed Kyle's performance on several tasks associated with somatodyspraxia, including in-hand manipulation and diadokokinesia. Both skills were within normal limits (Exner, 1992, 2001; Wilson et al., 2000).

We asked Kyle about his most and least favorite things at school and home. He could not easily articulate his likes and dislikes. He said he really did not like school but if he had a favorite subject, it was reading. He could not specify any play activity he really enjoyed except for using the swings. He said he was the last person chosen for teams. He did not like going to the mall. When asked the name of his best friend, he mentioned his younger sister.

Other Information

The findings of other professionals can be very helpful when interpreting the results of an assessment of SI. Kyle had been given the Wechsler Intelligence Scale for Children-Revised (WISC-R) by the school psychologist. His score was 130 on the verbal portion and 114 on the performance portion. These scores suggested that Kyle's difficulties on SIPT tests could not be explained by cognitive limitations.

HERE'S THE POINT

- Evaluation is a process involving data collection from multiple sources.
- A complete evaluation of SI may include a parent interview to develop an **occupational profile,** standardized testing, and structured clinical observations as well as observations in the classroom, on the playground, and in other pertinent environments.
- Using multiple sources of information provides the therapist with a broad picture of the child across multiple contexts and provides insights into how caregivers and other professionals see the child's strengths and needs.

PRACTICE WISDOM

As you engage in the evaluation process, keeping in mind the need to collect data from multiple sources and across multiple contexts, it is also important to appreciate that any assessment is a reflection of one "snapshot" in time. You have done your best to identify the most appropriate assessment tool and done your homework relative to that tool's reliability and validity. You are well versed in test administration and interpretation; in short, *you* are as prepared for this evaluation session as you can be, reducing two forms of bias, or assessment error, as much as possible. You may also have done your best to prepare the parent and child for what to expect from the evaluation session. Nonetheless, many things can interfere with your ability to tap into the child's "true" skill or performance. Anxiety and stress may play a role here; some children will be well aware that decisions will be made based on their performance today. Mood, fatigue, and illness also can influence performance. How do you know if the data that you collect are a "good" reflection of the child's actual ability? Your use of multiple sources of information will help you decide; if the data you collect in your snapshot are out of sync with parent or teacher interview information, or if scores on one test seem to contradict those on another, something is amiss. Interpretation of data requires a great deal of preparation and some detective work as you put the pieces together. It requires that you consider performance across multiple contexts (e.g., personal, social, physical, temporal, cultural) as you work to understand the strengths and needs of the child that you are evaluating.

Research Related to Sensory Integration and Praxis Patterns

Before we explain how we interpret the assessment information that we have on Kyle, we need to revisit some background information. Table 11-3 summarizes the research studies conducted by Ayres and others that provide the foundation for understanding the main patterns of SI functioning of children with and without disabilities. We touched in these in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests). Ayres initiated this research in the 1960s and continued this path of systematic inquiry until the end of her career. Since that time, other researchers have followed similar methods of examining these patterns, yielding both verification of previous findings as well as refinement and evolution of the understanding of relationships among sensory integrative functions.

Ayres' use of factor analysis with numerous samples of typical and atypical children informed her theory, led to new and revised assessment tools, and guided the development of her intervention principles. The patterns of SI that emerged during several decades were highly consistent, leading to increased confidence about the relationships between specific sensory and motor functions (Ayres, 1965, 1966a, 1966b, 1969, 1971, 1972, 1977, 1989; Ayres, Mailloux, & Wendler, 1987). The early studies examined correlations among various measures, including clinical observations of neuromotor functions,

Text continued on page 271

TABLE 11-3 Patterns of Sensory Integration Constructs Identified in Research

Patterns Found in Studies Examining Comprehensive Sensory Integration Constructs					
VISUOPRAXIS/ VISUODYSPRAXIA	**SOMATOPRAXIS/ SOMATODYSPRAXIA**	**POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING**	**SOMATOSENSORY PERCEPTION RELATED**	**AUDITORY LANGUAGE RELATED**	**TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER**
Ayres (1965). In this first published factor analysis, Ayres reported patterns of SI that were demonstrated in a sample that included both typically developing children and children with identified learning or behavioral problems. This study was conducted with some of the earliest versions of her own tests and structured observations, as well as some other common tests of the period. The main patterns found in this first study remained remarkably consistent in the future studies conducted. Importantly, this first study established the first evidence of discriminative validity in the SI measures. A strong relationship demonstrated between factors in this early study also informed the concept of SI.					
In this first analysis, a separate factor characterized mostly by a test of Figure-Ground discrimination foreshadowed the emergence of possible "higher level" or hemispheric-related patterns that were seen in later studies.	This first analysis also demonstrated the clear and strong relationship between tests of tactile perception and the tests measuring motor planning, which, in this study, included an early form of the Imitation of Postures Test (from the SCSIT; later known as Postural Praxis) as well as a test of motor accuracy and a manipulative test known as the Grommet Test.	Although Ayres was not yet studying the role of the vestibular system in 1965, she was already interested in postural and ocular mechanisms. This study revealed a pattern characterized by right-left discrimination, avoidance of crossing the body midline, difficulty with rhythmic activities, and poor eye-hand agreement. This grouping of scores intrigued Ayres as they seemed to represent some set of dysfunction that was different than the type of dyspraxia revealed in the tactile and motor planning grouping of scores.	Shared loadings on the visual perception tests by Frostig, along with early versions of the Kinesthesia and Manual Form Perception tests, as well as the Ayres' Space Test, demonstrated a pattern that has similarity with later patterns that show associations between sensory perception tests in more than one sensory system, without the motor tests. In this study, the pattern included tests of tactile, proprioceptive, and visual perception.	Although Ayres was interested in the role of auditory and language functions she considered these areas somewhat out of her professional domain and only included tests in these areas on occasion.	One of the most salient findings in this study was that the variable of tactile defensiveness did not load with the tests of tactile perception, and instead showed a stronger relationship to measures of hyperactivity, distractibility, and other behavioral measures.

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Ayres (1966a). This study included both typically developing children and a subset (about 10%) of children with identified problems. Similar tests and structured observations as were applied in the 1965 study were included.					
The Frostig spatial relations test, as well as the Ayres' Space Test and other measures of perceptual-motor skills and visual perception, revealed a visual motor pattern in this study, similar to a pattern later called visuopraxis.	The pattern which accounted for most variance in this study was characterized by loadings on tests of motor planning in association with tests of tactile perception and kinesthesia.	No factor found. See the Ayres (1966b) study in the text that follows; mostly typically developing children in this study as well.	No factor found	Not tested	A mild association between tactile defensiveness and praxis was seen in this study.
Ayres (1966b). With similar measures to the 1966a study, this factor analysis included only typically developing children.					
An association between the Frostig tests, Ayres' Space Test, Motor Accuracy, & Figure-Ground discrimination accounted for most variation in this group.	In this study, which included only typically developing children, the association between poor motor planning and tactile perception, seen in most other studies, was not demonstrated.	An association between postural, ocular, and bilateral integration functions was not seen in these typical children. There was a mild relationship between bilateral integration and tactile perception.	No factor found	Not tested	An association between tactile defensiveness and hyperactivity revealed in this analysis led Ayres to suggest a possible maturational factor for the relationship of these variables.

Continued

TABLE 11-3 Patterns of Sensory Integration Constructs Identified in Research—cont'd

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Ayres (1969). This study examined the relationships between the SCSIT and measures of psycholinguistic abilities, intelligence, auditory functions, postural-ocular reactions, and academic achievement in children with "educational handicaps."					
Possible right hemisphere dysfunction noted with better right- than left-sided functions	A significant relationship between tactile perception and motor planning was demonstrated again in this study.	A factor of bilateral integration and postural reactions was demonstrated with an association to reading and language problems.	No factor found	A possible left hemisphere dysfunction factor was hypothesized characterized by an association between measures of auditory language, reading achievement, and auditory and visual-motor sequencing.	Continued association between tactile defensiveness, hyperactivity, and attention was seen in this study, but not as a distinct factor.
Ayres (1971). The aim of this analysis was to examine the ability of measures to predict the severity of SI problems in a larger sample of children with learning problems. In this study, she found similar prevalence of dyspraxia and postural and bilateral coordination problems.					
	Tactile perception and praxis were once again linked and the Imitation of Praxis Test from the SCSIT (similar to the Postural Praxis Test on the SIPT) was the best predictor of dyspraxia.	The ability to assume a prone extension posture was the best predictor of problems in postural-bilateral integration.			
Ayres (1972). This factor analysis confirmed similar patterns to those identified in previous studies in the same sample of children with learning problems who were analyzed in the 1971 regression analysis. Because of the mounting expectations for rigor in research, alongside the fact that there were no available standardized measures for sensory responsiveness, this was the last study conducted by Ayres in which nonstandardized measures for functions such as tactile defensiveness were included.					
Form and space perception factor emerged, suspected to be possibly related to some aspect of right hemisphere deficits.	In a variation from most other studies, motor planning was associated with hyperactivity and tactile defensiveness in this analysis. This finding, along with the significant	Poor ocular control associated with evidence of some primitive postural responses.	Tactile perception and hyperactivity formed a factor separate from praxis.	Auditory language measures loaded with intelligence.	Tactile defensiveness and hyperactivity loaded with praxis.

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
	associations between patterns seen in this and most other studies, demonstrated that problems in sensory responsiveness and behavior may occur in conjunction with various types of sensory integrative patterns.				
Mailloux et al. (2011). This study aimed to clarify the role of the Post-Rotary Nystagmus (PRN) test in the vestibular bilateral integration patterns and to revisit the associations between measures of tactile defensiveness and other SI functions. This sample included few children with prolonged PRN, thus avoiding the "canceling out" effect of the presence of both high and low PRN which most likely occurred in most previous studies.					
A visuopraxis factor was present that includes some aspects of somatopraxis as well.	The relationship of tactile perception and praxis as somatopraxis, loaded on same factor as measures of visuopraxis.	PRN showed significant loading on the factor of bilateral integration and sequencing. The presence of Motor Accuracy was hypothesized as being related to ocular control and midline integration.	Tactile perception tests loaded with a test of visual perception	No factor found	Tactile defensiveness items loaded with signs of attention problems
Patterns Found in Studies Examining Sensory Perception and Praxis Without Variables of Sensory Responsiveness					
Ayres (1977). Factor analysis with a sample of children with learning disabilities; first study to include a measure of PRN.					
Visuopraxis factor characterized by four visual perception tests from SCSIT plus Manual Form Perception Test (tactile test with a visual element).	Praxis tests associated with a composite of tactile perception tests and Kinesthesia test.	Lack of bilateral integration measures on factor associated with prone extension and composite postural measures suggest the grouping of scores may have been more similar to the somatosensory-related patterns in which two or more sensory systems load.	Prone extension associated with composite postural measures, plus flexion posture, composite tactile scores, and Kinesthesia test.	All auditory language measures loaded together (composite language on the Illinois Test of Psycholinguistic Ability, dichotic listening, and Flowers-Costello test).	Not tested

Continued

TABLE 11-3 Patterns of Sensory Integration Constructs Identified in Research—cont'd

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Ayres, Mailloux, & Wendler (1987). This study of 182 children with SI or learning difficulties bridged the SCSIT and the preliminary forms of the new praxis tests that would be added to the SIPT. Exploration of the use of cluster analysis in this study, as well as in later cluster analyses, demonstrated results separated by severity rather than differences in types of SI and praxis.					
A combined visuopraxis and somatopraxis factor was demonstrated with strong associations between praxis, tactile sensory processing, visual perception, and repeating of sentences.	Praxis and somatosensory tests associated again in the combined visuopraxis and somatopraxis factor.	No factor found	A kinesthesia factor was demonstrated.	Auditory memory factor seen; again, measures of auditory language functions did not associate significantly with any one SI pattern.	Not tested
Ayres (1989). Multiple factor analyses are conducted with a large data set from the SIPT standardization project. Representative analyses chosen for the manual included three samples (one group of only typically developing children, one of only children with SI and/or learning problems, and one combined sample).					
Visuopraxis factor in all groups characterized by consistent presence of Constructional Praxis, Design Copying, Space Visualization, Figure-Ground, and Motor Accuracy.	Somatopraxis factor characterized by consistent presence of Postural Praxis, Oral Praxis, and Graphesthesia, with Bilateral Motor Coordination, Standing and Walking Balance, Praxis on Verbal Command, and Sequencing Praxis in some of the groups. A cluster analysis with a combined sample revealed a grouping of both visuopraxis and somatopraxis scores.	A bilateral and sequencing factor was characterized by the tests of Bilateral Motor Coordination, Standing and Walking Balance, Sequencing Praxis, and Graphesthesia. The absence of tactile tests and core praxis tests such as Postural Praxis suggested this pattern was most similar to vestibular and postural/ocular-based patterns related to bilateral integration, as seen in previous studies.	Several variations of sensory perception-based factors emerged, with one or more tactile tests loading with a test measuring sensory perception in another sensory system (e.g., proprioception or visual perception).	The Praxis on Verbal Command pattern, characterized by high PRN, low Praxis on Verbal Command, and most other scores within normal limits was hypothesized to represent a probably left hemisphere or auditory language deficit that on its own was not considered sensory integrative in nature.	Not tested

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Mulligan, 1998. In this large study, the scores of more than 10,000 children were analyzed from the data bank of SIPT scores stored at the publisher, during a period of time when the test was scored by a mail-in process. Both confirmatory (CFA) and then exploratory factor analyses (EFA) were conducted on this data set.					
On both CFA and EFA, a visuopraxis factor was identified by all visual perception and visual praxis tests of the SIPT.	In the CFA, Oral Praxis, Postural Praxis, and Graphesthesia loaded, in a similar way to the 1989 Ayres study. In the EFA, only Oral Praxis and Postural Praxis loaded on this factor.	In both the CFA and EFA, a bilateral integration and sequencing factor was identified with loadings on the tests that measured these two functions.	In both the CFA and EFA, a factor characterized by tactile perception tests was evident.	No factor found	Not tested
Van Jaarsveld et al., 2014. This study examined patterns of SI dysfunction in 223 children in South Africa. Both confirmatory (CFA) and exploratory factor analyses were conducted.					
In both the CFA and EFA, a factor that was largely characterized by tests of visual perception and visual praxis was evident, with some loading of tests associated with somatodyspraxia, similarly to the visuodyspraxia and somatodyspraxia factor reported by Mailloux and colleagues (2011).	Somatodyspraxia seen as part of the visuodyspraxia factor in this study.	A bilateral and sequencing factor was identified similar to the Mulligan, 1998 study.	In this study, Localization of Tactile Stimuli and Manual Form Perception loaded on a factor.	No factor found	Not tested

Continued

TABLE 11-3 Patterns of Sensory Integration Constructs Identified in Research—cont'd

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Patterns Found in Studies Examining Sensory Responsiveness Without Variables of Sensory Perception and Praxis					
Dunn & Brown, 1997. Based on FA of Sensory Profile data from more than 1,000 children with and without disabilities, Dunn (1997) hypothesized that there is a relationship between a person's nervous system operations and self-regulation strategies					
	Not tested	Not tested	Not tested	Not tested	Four patterns of sensory processing emerged as described in Dunn's model: sensation seeking, sensation avoiding, sensory sensitivity, and low registration.
Baranek et al., 2006. Caregivers of 258 children designated as Autism, PDD, DD/ID, Other DD, or Typical ages 5 to 80 completed the Sensory Experiences Questionnaire.					
	Not tested	Not tested	Not tested	Not tested	The ASD group presented more sensory symptoms than either the Typical or DD groups and presented hyporesponsiveness in both social and nonsocial contexts. Hyperresponsiveness was similar in the Autism and DD groups, but significantly greater than in the Typical group.
Su, C., & Parham, L.D., 2014. CFA using SPM results revealed that tactile, vestibular–proprioceptive, visual, and auditory systems form distinct, valid factors that are not age dependent as opposed to other models that found factors of over- or underresponsiveness within or across sensory systems.					
	Not tested	Not tested	Not tested	Not tested	Sensory history questionnaires provide a valid means by which to measure sensory constructs

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
Kirby et al., 2015. Using a scoring supplement to the Sensory Processing Assessment for Young Children, an observational measure on three groups of children, ASD (n = 540), DD (n = 537), and typical (n = 539), to characterize sensory interests, repetitions, and seeking behaviors (SIRS).					
	Not tested	Not tested	Not tested	Not tested	Differences between groups were identified in frequency and intensity of overall SIRS, complexity of SIRS, and incidence of particular types of SIRS (i.e., posturing, sighting, proprioceptive seeking, spinning). Facial affect was primarily neutral during engagement in SIRS across groups.
Patterns Found in Clinical Populations					
Autism spectrum disorder (ASD) **Smith Roley et al., 2015** (Average mean scores on SV, FG, DC, CPr)	ASD **Smith Roley et al., 2015** (Low mean scores on somatosensory tests and PPr, OPr, SPr, PrVC, BMC)	ASD **Smith Roley et al., 2015** (Low mean scores on BMC, PRN; lowest mean score out of all 17 tests on SWB)	ASD **Smith Roley et al., 2015** (Low mean scores on KIN, MFP, FI, GRA, LTS, PRN, SWB)	ASD **Smith Roley et al., 2015** (Low mean score on PrVC)	ASD **Smith Roley et al., 2015** (Low scores on SPM)
		Cochlear implants **Koester et al., 2014** (Low mean scores on SWB, PRN, and low average SPr, MFP, BMC, and MAc; all other mean scores in the typical range)	ADHD **Mulligan, 1996** Somatodyspraxia and vestibular deficits (Low mean scores on KIN, GRA, PPr, OPr, SPr, PrVC, DC, and SPR with relatively good scores on visual praxis except DC)		ASD **Lane et al., 2010** Using Cluster analyses (CA), 3 patterns of sensory processing emerged in 54 children with ASD and their association with adaptive behavior. Subtypes emerged differentiated by taste and smell sensitivity and sensory-related movement and predicted communication competence and maladaptive behavior. Suggested that sensory differences are salient in ASD and may be of different types

Continued

TABLE 11-3 Patterns of Sensory Integration Constructs Identified in Research—cont'd

VISUOPRAXIS/ VISUODYSPRAXIA	SOMATOPRAXIS/ SOMATODYSPRAXIA	POSTURAL/OCULAR/ VESTIBULAR BILATERAL INTEGRATION & SEQUENCING	SOMATOSENSORY PERCEPTION RELATED	AUDITORY LANGUAGE RELATED	TACTILE DEFENSIVENESS/ SENSORY RESPONSIVENESS/ SENSORY PROCESSING DISORDER
		ASD **Siaperas et al., 2012** (M-ABC, SWB, and BMC)	ASD **Siaperas et al., 2012** (KIN, GRA, LTS, PPr, SPr)		**Lane et al., 2011.** Using Confirmatory Cluster Analysis (CCA), 33 children with ASD were provided the Short Sensory Profile. The three sensory subtypes reported in 2010 emerged and differed based on severity, taste/smell sensitivity, and vestibular/proprioceptive processing. Children with sensory-based inattention could be identified as sensory seekers or non-seekers. Children with vestibular/proprioceptive dysfunction differed on movement and tactile sensitivity.
					ASD **Lane et al., 2014.** Cluster analysis was used to extract sensory subtypes based on caregiver responses on the Short Sensory Profile with 228 children with ASD aged 2 to 10 years. This study revealed four sensory subtypes: sensory adaptive, taste smell sensitive, postural inattentive, and generalized sensory difference. The sensory subtypes differed in the *severity* of reported sensory differences and the type of sensory differences. Authors suggest two possible mechanisms of sensory disturbance in autism: sensory hyperreactivity and difficulties with multisensory processing.

PDD = pervasive developmental disorder; DD = developmental disability; ID = intellectual disability.

sensory responsiveness, and standardized test scores from the original Southern California Sensory Integration Tests (SCSIT) or the later SIPT (Ayres, 1989).

Mulligan (1998) later replicated Ayres' patterns using confirmatory factor analysis on a sample of 10,000 children who were clinically referred. More recently, Mailloux and colleagues (2011) and van Jaarsveld and colleagues (2014) conducted factor analytic studies that yielded similar findings.

As summarized in Table 11-3, the most common patterns to emerge in the various studies were **visuopraxis/visuodyspraxia; somatopraxis/somatodyspraxia;** postural/ocular/**vestibular bilateral integration and sequencing;** deficits associated with somatosensory perception; problems related to tactile defensiveness/sensory responsiveness; and problems related to auditory/language issues.

Ayres' earliest studies included nonstandardized measures of sensory responsiveness, most commonly tactile defensiveness and, occasionally, gravitational insecurity. In order to adhere to evolving psychometric standards, Ayres avoided inclusion of nonstandardized tools in later studies; thus, sensory responsiveness variables were not included in her studies in the 1980s. The advent of standardized questionnaires that focus on sensory responsiveness, such as the Sensory Profile (SP; Dunn, 1997), Sensory Profile 2 (SP2; Dunn, 2014), and the Sensory Processing Measure (SPM; Parham, Ecker, Miller-Kuhaneck, Henry, & Glennon, 2007), allowed greater exploration of these sensory integrative functions. Dunn (1997) proposed an interaction between neuronal threshold and behaviors that resulted in low registration, sensory seeking, sensory avoiding, or sensory sensitive responses. Su and Parham (2014) found that, consistent with Ayres Sensory Integration (ASI) theory, item responses on a sensory questionnaire formed discrete factors consisting of individual sensory systems (tactile, visual, auditory, etc.).

Most of the studies examining SI patterns have employed either the standardized questionnaires focused on sensory responsiveness (i.e., the SP or SPM) or the standardized direct measures of sensory perception and motor-related sensory integrative functions, such as bilateral integration and praxis. However, when Mailloux and colleagues (2011) included measures of tactile defensiveness and attention (alongside measures from the SIPT), these variables loaded together on a single factor, consistent with the way in which these variables were associated in Ayres' early studies.

Other studies also have examined these patterns within clinical groups, such as children with autism (Baranek, David, Poe, Stone, & Watson, 2006; Dunn & Brown, 1997; Kirby, Dickie, & Baranek, 2015; A. E. Lane, Dennis, & Geraghty, 2011; A. E. Lane, Young, Baker, & Angley, 2010; A. E. Lane, Molloy, & Bishop, 2014; Siaperas et al., 2012; Smith Roley et al., 2015), children with attention deficit-hyperactivity disorder (Mulligan, 1996), and children with cochlear implants (Koester et al., 2014). These studies show that, for some diagnostic groups, distinct patterns of sensory integrative deficits may be observed.

HERE'S THE EVIDENCE

Ayres provided a model by which to validate her theory of SI (Ayres, 2005). In a modern sample using factor analysis, Mailloux and colleagues (2011) examined the relationships among the SIPT (Ayres, 1989), items on the SPM (Parham et al., 2007), and measures of attention. The researchers found results that further validated the patterns of SI dysfunction found previously by Ayres during several decades summarized in Table 11-3 and by Parham and Mailloux (2015). In a subsequent study on children with autism, Smith Roley and colleagues (2015) reported that individuals with autism had somatodyspraxia, vestibular postural deficits, and sensory reactivity deficits without significant differences in visual praxis. Tests of imitation praxis correlated most highly with social participation, showing that dyspraxia is a key element contributing to difficulties with social participation in this sample with autism. The application of the rich history of factor analyses on the SIPT and related measures informs therapists of patterns that exist in various populations and, therefore, informs assessment as well as intervention.

HERE'S THE POINT

- Systematic inquiry informs our understanding of the patterns of sensory integrative dysfunction, which, in turn, guides our clinical reasoning during the assessment process.

- Understanding the relationships among sensory systems, and how they relate to attention, language, motor control, and praxis, allows the therapist to interpret a child's assessment data at a deep level and relate findings to the presenting problems.
- Knowledge of these relationships is critical for the therapist to judge whether intervention is indicated, and, if so, what type of intervention is appropriate and what particular outcomes should be expected.

CASE STUDY: KYLE: INTERPRETING THE RESULTS

The research reviewed here provides a foundation for interpreting the evaluation data that we have collected on Kyle. Our goal was to determine if sensory integrative dysfunction explained some of Kyle's difficulties. We had quite a lot of information to organize and interpret. In Table 11-4, we separated Kyle's presenting problems and sensorimotor history, relevant background information, and information obtained from testing.

Next, we examined the test results (see Tables 11-1, 11-2, and 11-4) to look for meaningful clusters that would be suggestive of specific types of sensory integrative dysfunction. We were aware that some of Kyle's test results would not fit into clusters reflective of sensory integrative dysfunction, and we remained cognizant that such isolated observations would not help us clarify Kyle's problems from the perspective of SI theory.

To facilitate the process of looking for meaningful clusters, we used the Interpretation Worksheet, Table 11-5. Evidence of possible dysfunction was defined as a SIPT score below 1.0 SD or a clinical observation considered problematic for a 6½-year-old child (see also Chapter 8, Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests). We have highlighted these in red.

After Kyle's test results were recorded on the Interpretation Worksheet, we examined the pattern of his behaviors and performance. It is notable that, although there are many concerns, when interpreted appropriately, this did not mean that Kyle had dysfunction in every domain.

Meaningful Clusters

Only one rule exists with regard to meaningful clusters. With one exception, tests and observations listed in the Sensory Modulation category, no single red highlight constitutes a cluster. All the scores in red in Sensory Modulation reflect multiple observations and, therefore, qualify as clusters. Otherwise, the number of test scores that must be low or observations that must be present to conclude there is evidence of a meaningful cluster is a matter of clinical judgment. To say that a meaningful cluster exists, we attempt to capture the most important aspects of a construct. Next, we provide an example of the reasoning associated with the determination of meaningful clusters.

Using the Interpretation Worksheet

To conclude that sensory integrative dysfunction was the source of Kyle's difficulties, we needed to find evidence of a sensory processing deficit. Kyle had several scores that suggested central vestibular and proprioceptive processing deficits. They can be seen in the categories labeled "Postural Control" under Vestibular, and "Proprioception" under Somatosensory. As is always the case when identifying vestibular-proprioceptive processing deficits, our interpretation relied heavily on clinical observations. Although his score on the Kinesthesia test was within normal limits, this test is a measure of passive joint movement, which is not the best measure of proprioception (see Chapter 8, Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests).

When we examined Kyle's tactile testing, the results were less clear. Two scores, Graphesthesia (GRA) and Manual Form Perception (MFP), were below −1.0 SD. However, Ayres found associations between GRA and bilateral integration and sequencing (BIS) deficits, and MFP is also a test of form and space perception. (Although GRA also has a form and space component, Ayres never found it to load strongly on that factor.) Because both of Kyle's more "pure" tactile discrimination test scores, Localization of Tactile Stimuli and Finger Identification, were within normal limits, we examined the categories of BIS and form and space perception before deciding whether Kyle's low scores on MFP and GRA reflected poor tactile discrimination.

TABLE 11-4 Summary of Relevant Information Obtained by Report and Through Observation

Kyle's Presenting Problems

Parental and Teacher Concerns

- Believes he can't do anything right and is developing a poor self-image
- Distractible
- Behavior becomes worse in crowded or noisy situations
- Follows directions given to other children standing close to his desk
- Easily disrupted or distracted by other children
- Increased activity
- Ambulatory Kyle in constant motion
- Runs from place to place without stopping to engage in activity
- Behavior becomes worse in crowded or noisy situations
- Races around playground seemingly without purpose
- Difficulty sitting still for prolonged periods
- Clumsiness (see sensorimotor development)
- Lack of friends
- Not finishing his schoolwork

Related Behavior

- Hates school; developed stomachaches and excuses to remain at home
- Gets frustrated and tears up papers
- Does not play or interact with friends or classmates

Sensorimotor Development

- Difficulty nursing; weak suck; tired quickly
- Sat independently at age 8 months, walked at age 15 months; never crawled
- Fell frequently, bumped into things, knocked over things
- Seemed to prefer right hand but tended to use hand closest to objects
- Awkward when he walked and ran
- Unable to catch; throwing awkward, inaccurate
- Did not know how to pump swing
- Loved to be pushed on swing, would swing for hours
- Difficulty propelling bicycle (with training wheels)
- Problems with coloring, artwork, and puzzles
- Laid his upper body on the table when coloring, and so on
- Fell off chair
- Illegible handwriting
- Erased his papers until there were holes in them

Related Background Information

Developmental History

- Full-term, uncomplicated birth
- Cranky, irritable baby who disliked cuddling and handling
- Erratic sleep cycles; did not sleep for more than 4 hours at a time until age 2 years
- Seldom sleeps more than 6 hours
- History of chronic ear infections

Strengths

- Loving and lovable child
- Mother believes he is bright
- Language skills developed ahead of schedule
- Sense of humor

Related Test Results

Verbal IQ, 130; performance IQ, 114 (WISC-R)

Evaluation of SI Functioning

Behaviors Observed at School

- Scissors skills slow and labored but adequate for task
- Fell out of chair
- Difficulty opening milk container

Clinical Observations of Posture

- Poor prone extension posture
- Head lag when assuming supine flexion
- Hypotonia of extensor muscles
- Lordotic standing posture, tendency to lock his knees
- Poor proximal stability in quadruped
- Equilibrium better than static, controlled postures
- Deficient tilt board response
- Used too much force to open milk container

Clinical Observations of BIS

- Difficulty with bilateral and projected action sequences (e.g., catching a ball, jumping with two feet together, doing jumping jacks)
- Difficulty crossing the midline

Clinical Observations of Somatopraxis

- Unable to maintain supine flexion

Indicators of Poor Sensory Modulation

- Responded aversely to light touch stimuli
- Dislike of glue or finger paint on his fingers
- Sensitive to noise
- Rubbed arms and hands after application of tactile stimuli
- Made excuses to quit testing during tactile tests
- SP2: sensory over-responsivity to touch, sound; movement seeking
- No gravitational insecurity
- No evidence of an aversive response to vestibular stimulation

TABLE 11-5 Kyle's Completed Interpretation Worksheet

VISUAL	SCORE	VESTIBULAR	SCORE	SOMATOSENSORY	SCORE	INTEROCEPTION/ SENSORY MODULATION	SCORE
Visual Spatial		**Postural Control**		**Proprioception**		**Sensory Responses**	SOR to touch, sound; no GI or aversion to movement
		SWB	–2.04	KIN	–0.24		
SV	–1.47	Prone extension	Weak	SWB	–2.04	Over/Under	
FG	–0.67			Poor body scheme	Yes	Fluctuating	
Visual Praxis		Stability	Poor				
		Righting	Poor	Observations (e.g., Finger/ nose thumb/ finger touching, diadokokinesis)	OK	**SP2 results**	
DC	–1.69	Equilibrium	Poor			Auditory	33
CPR	–2.32	**Vestibular-Ocular**				Vision	11
MAC	–1.42					Touch	42
		Low PRN	–1.43			Movement	24
Haptic Form and Space		Ocular stability	Mod	**Tactile**		Body position	15
		Head/neck/eye coordination	Poor	LTS	+1.34	Oral	23
MFP	–1.25			GRA	–2.13	SP2 quadrants	
GRA	–2.13			FI	–0.81	Sensory seeking	49
				MFP	–1.25		
		BILATERAL INTEGRATION	**SCORE**	**PRAXIS**	**SCORE**	Sensory avoiding	50
						Sensitivity	55
Observations		BMC	–2.21	PPr	–1.52	Registration	25
		SPr	–3.00**	OPr	–2.72	SP2 behavior	
		OPr	–2.72	PrVc	–0.92	Conduct	22
		GRA	–2.13	(SPr)	–3.00**	Social emotional	45
		MFPII		(BMC)	–2.21		
		MAC	–1.42	Flexion	Head lag	Attentional	28
		Observations (e.g., skipping, jumping jacks)	Poor	Observations (e.g., play)	Constant motion, purposeless; awkward movement; unable to throw/ catch; diff w/ scissors; diff w/ projected action sequences	Observations	
						Arousal	Hi
						Affect	OK
						Activity level	Hi
						Attention	Poor

TABLE 11-5 Kyle's Completed Interpretation Worksheet—cont'd

RIGHT HEMISPHERE IQ	SCORE	LATERALITY	SCORE	PRAXIS ON VERBAL COMMAND	SCORE	LEFT HEMISPHERE IQ	SCORE
Low Performance	P114	SVCU	–1.05	PrVC (low)	No	High performance	No
High Verbal	V130	PHU	+0.62	PRN (average to high)	No	Low verbal	
Poor visual spatial SV, FG, FI, DC	Yes	R/L differences		Poor sequencing	Yes	Poor sequencing	
Significantly lower left-sided scores	No	Poor scores on directionality, reversals, inversions, jogs		Possible low scores on: OPr, SPr, BMC, SWB, DC	Yes		
Low frustration tolerance		Observations					

NOTE: A difference of greater than 12 points between verbal and performance IQ scores is atypical. Thus, in spite of overall high scores for both verbal and performance IQ, the discrepancy between scores needs to be considered.
**Scores lower than –3.0 are reported by Western Psychological Services as –3.0.

Given the number of indicators of deficits in BIS, we believed Kyle's GRA score likely was reflective of dysfunction in that area. Similarly, because he had several other indicators of form and space deficits, we interpreted his low MFP score as reflective of that category. Therefore, we concluded that Kyle did not have a meaningful cluster suggestive of deficits in tactile discrimination.

Kyle did not have a problem with over-responsivity to vestibular or proprioceptive sensation; he demonstrated no evidence of gravitational insecurity or aversive responses to movement. However, our observations and Kyle's SP2 scores confirmed that he had a sensory modulation dysfunction, with over-responsiveness in the tactile and auditory systems, and also reflected in "sensory avoiding" in the quadrant score. Kyle also showed "sensory seeking," mostly related to his high activity level. Through the SP2, these modulation difficulties were linked to lowered self-esteem as well as low tolerance for frustration when tasks became difficult. Kyle's modulation difficulties also appeared to influence his activity level.

Having found evidence of deficits in sensory processing, we looked for difficulties in other domains assessed by the SIPT that might result from poor sensory processing (see Table 11-5). Assessment of BIS revealed evidence of dysfunction by low scores on Bilateral Motor Coordination and Sequencing Praxis as well as clinical observations.

We then examined evidence for somatodyspraxia, for which there are two major distinguishing characteristics: deficits in both bilateral projected action sequences *and* more feedback-dependent motor actions and tactile or proprioceptive (somatosensory) processing (see Chapter 5, Praxis and Dyspraxia).

Postural Praxis (PPr) is the best indicator of somatodyspraxia. Kyle's PPr score was –1.52. However, both Ayres and Mulligan found weak loadings of PPr on the BIS factor (see Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited, and Chapter 8, Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests, respectively). Furthermore, because Kyle did not have a deficit in tactile discrimination, we had to reject the possibility that he had somatodyspraxia.

The conclusion that Kyle did not have a deficit in **Praxis on Verbal Command (PrVC)** was much easier. This dysfunction is characterized by prolonged Post-Rotary Nystagmus (i.e., score greater than + 1.0) and a low PrVC score. Kyle had *depressed* nystagmus and a normal PrVC score. In fact, Kyle had a relative strength in translating verbal commands into motor actions.

So far, we had concluded that Kyle had deficits in interpreting sensation derived from active movement (i.e., vestibular and proprioceptive

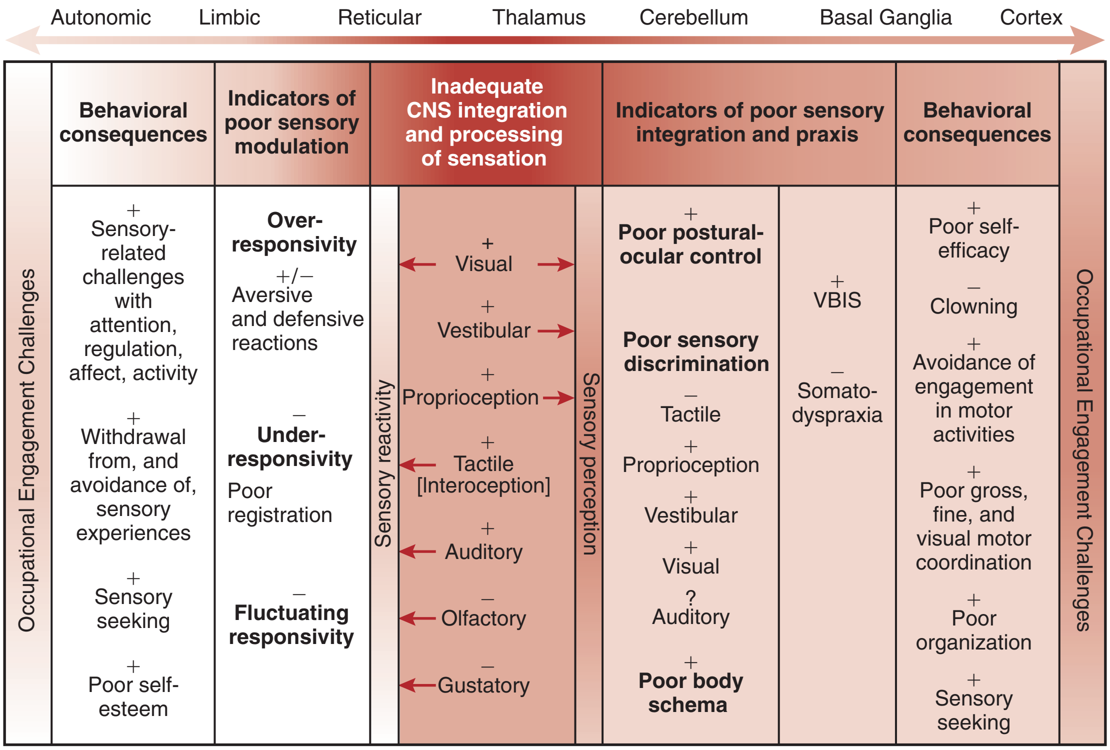

FIGURE 11-1 Kyle's sensory integration profile.

sensation); these deficits, in turn, resulted in difficulty planning and producing bilateral and projected action sequences (see Table 11-5). Kyle did not have difficulty with praxis tasks that relied on feedback, as would have been seen with somatodyspraxia. We had identified over-responsiveness to the sensations of touch and sound but also had found that Kyle showed some sensory-seeking (movement) and had adequate modulation of other sensations. Modulation difficulties were linked to increased activity level and had a negative influence on his self-esteem and ability to make friends. Furthermore, we had identified strength in translating verbal commands into motor actions. We then examined evidence of difficulty in any of the common end products of sensory integrative dysfunction: form and space perception, visual motor coordination, or construction.

Although Kyle's Figure-Ground (FG) score suggested a relative strength, the other test scores in these areas revealed difficulties in all three end product areas. Unlike the other tests in this category, FG is entirely a test of form perception; thus, it is not surprising that if one test result were different from the others, it would be FG (see Chapter 7, Sensory Discrimination Functions and Disorders, for more information on visual perception).

The Final Stage of Interpretation

We used the model in Figure 11-1 for the final stage of interpretation. We placed a plus or a minus above each construct to reflect whether there was a meaningful cluster providing evidence of dysfunction. We used a "?" when we were not certain and a "-/+" to indicate only some aspects of the described construct. We placed pluses above each of the constructs for Kyle:

- Vestibular, proprioceptive, tactile, and auditory processing
- Postural-ocular control
- Sensory discrimination (proprioception, vestibular, visual)
- Poor body scheme
- Vestibular Bilateral Integration and Sequencing
- Poor self-efficacy
- Avoidance of motor behavior

- Sensory-seeking
- Over-responsivity (–/+; in some systems)
- Sensory-related challenges with attention, regulation, affect, activity
- Avoidance of sensory experiences
- Poor self-esteem

In determining whether meaningful clusters existed, we addressed two bigger questions: Is there evidence of sensory integrative dysfunction? And, if so, what is the nature of the dysfunction? The latter question ultimately leads to a third question: What will intervention resemble? More specifically, what type (or types) of enhanced sensation will we include? What will be the desired characteristics of adaptive interactions?

Reporting the Results

Reporting the results of Kyle's evaluation involved communicating in a manner that was meaningful to his parents and teacher and that would help them reframe many of his real-life difficulties in terms of sensory integrative dysfunction. We prepared a written report and met with Mrs. P. to discuss it.

The greatest concerns shared by both Kyle's parents and teachers were his distractibility and activity level. Therefore, we began with a discussion of sensory modulation deficits. Individuals who have sensory integrative dysfunction have difficulty with the meaningful interpretation of sensation. Often, they seem unable to "screen out" irrelevant details. Thus, they behave as though they are paying attention to everything around them. For example, all of us wear clothing that provides a source of continual sensory stimulation. However, we screen out that stimulation unless, for some reason, we begin to think about clothing. Similarly, although there may be noise in the hallway, we are able to concentrate on our conversation and screen out the irrelevant noise.

The results of Kyle's testing suggested that he had difficulty screening out irrelevant sensations and attending to only important information (e.g., instructions, schoolwork, a particular game). Thus, he appeared to be highly distractible. Because his distractibility was caused, at least in part, by an inability to screen out irrelevant stimuli, it became markedly worse when stimulation increased. Thus, it was understandable that his behavior deteriorated in busy places such as shopping malls or crowded restaurants. Similar difficulties occurred when Kyle's classmates congregated around the teacher's desk, all waiting for different instructions.

Kyle's negative reactions to touch likely came from a similar source. When Kyle became stressed, he translated light touch negatively. The more people touched him, either accidentally or to control his behavior, the less able he was to cope with it. Thus, his distractibility and increased activity, caused by his inability to screen out irrelevant stimulation, became a part of a vicious cycle. Kyle's "lashing out" at other children also seemed to be related to his inability to interpret the affective aspects of touch in a meaningful way.

Mrs. P. worried that Kyle was growing up feeling he could not do anything right. She believed that his negative self-concept was caused, in part, by all the reprimands he received during a typical day. Although his parents tried hard to emphasize Kyle's accomplishments, they also had to control his behavior. Thus, they found themselves saying "don't do that" far more often than they liked. This situation was even worse at school.

Mrs. P. believed that Kyle also felt bad about himself because he knew that he was poorly coordinated. The evaluation suggested that this might be related to his sensory processing difficulties as well. Kyle was aware that he had no friends and was never included in games because no one wanted him on their team. Mrs. P. was at a loss to deal with this problem; Kyle's appraisal of his motor skills was fairly accurate. She hoped she could come to understand his motor incoordination and find ways to help him improve it.

Without launching into a major description of vestibular-proprioception or factor analysis, we explained that many children who had poor motor planning abilities seemed to demonstrate coordination problems similar to Kyle's. Kyle's difficulties with catching and throwing a ball, jumping, knowing how much force to use, and deciding which hand to use were all related to his difficulties interpreting sensation about the position and movement of his body in space.

Because Mrs. P. seemed particularly interested in intervention to minimize Kyle's difficulties, we discussed different ways that an occupational therapist could provide services and the benefits generally associated with each type of intervention. If we were to provide direct intervention using the principles of SI theory, we would involve Kyle in activities that involved enhanced sensation and required Kyle to attempt new skills and master those that were emerging. We would carefully construct activities so they addressed Kyle's needs.

Although we believed Kyle's skills would improve markedly, all of us (i.e., Kyle, the occupational therapist, family, and teacher) would have to work very hard to improve Kyle's self-image. An improvement in Kyle's skills would not automatically result in a better self-concept. Mrs. P. expressed her willingness to think of creative ways to facilitate Kyle's participation with children in the neighborhood. We believed that coaching would be invaluable to Kyle's success at school, and we recommended that the occupational therapist there assume that role. In much the same way that we had interpreted Kyle's difficulties for Mrs. P., the school-based occupational therapist would explain Kyle's sensory integrative dysfunction to his teacher and help her develop new strategies for teaching him.

The school-based therapist might help the teacher rearrange the classroom or adapt assignments. Perhaps Kyle's desk could be moved from a high traffic area and his arithmetic answers could be written rather than glued into place. We planned to share the results of the evaluation with the school-based occupational therapist.

Mrs. P. seemed relieved that our explanation "fit" so well. She planned to discuss the report and recommendations with her husband. Together, they would decide how to proceed. Although we made numerous recommendations, the decisions rested with Kyle's family. We encouraged her to call with any questions.

When we talked with Mrs. P. the next week, she told us that she had requested occupational therapy services for Kyle at school. She was eager to make an appointment to develop goals. That process is the focus of Chapter 20 (Planning and Implementing Intervention Using Sensory Integration Theory).

Somatodyspraxia

In contrast to what we found with Kyle, Jackie shows a very different pattern of function and dysfunction. Here we present, in a much briefer format, a description of a child with somatodyspraxia, our evaluation data, and our interpretation of findings.

Praxis is a multidimensional concept that includes ideation, motor planning, and execution of new and novel tasks. For example, somatosensory-based praxis affects an individual's ability to use his or her body effectively within the environment, such as figuring out how to use the hands to open containers, navigate in and around obstacles, and to imitate and sequence actions. Somatodyspraxia often leads to difficulty initiating, organizing, and sequencing tasks, particularly those that are new and novel, and has ramifications for the speed of learning new tasks and engaging socially with others.

CASE STUDY ■ JACKIE

Jackie is described as a gentle, caring 7-year-old child with the diagnosis of speech and language delays. Her parents are concerned with her clumsiness, seemingly poor attention, high activity level, decreased emotional regulation, and difficulties in attaining academic success. Her teacher notes that she is more active than other children in the classroom but that her activity is not sufficiently purposeful. Jackie is often disorganized, has difficulty finding materials for classroom tasks, and is challenged when there are transitions.

Medical History

Jackie had repeated ear infections requiring tube placement at 3, 4, and 6 years of age. She also has asthma, which is controlled with medication.

Educational History

Jackie was kept in preschool an extra year and began kindergarten at age 6. She is now in first grade in a general education class.

Intervention History

Jackie was identified as having speech and motor delays in kindergarten. Since that time, she had been receiving individual occupational therapy services 30 minutes twice per month as well as speech and language therapy 30 minutes twice per month.

Developmental History and Other Parent Report

Jackie has frequent emotional upsets at school and sometimes will cry and hang onto her mother's leg when she gets dropped off at school. She often chews on her hair, especially when she is upset.

Gross Motor

Jackie appears clumsy and often falls. She does poorly in gym class and tries hard to fade into the background so she will not have to participate. On the playground, she does not run and play with other children. Although she will sit on the swings, she cannot pump for herself.

Fine Motor

Jackie has difficulty with buttons and snaps while dressing. She is clumsy at manipulating a pencil, and her formation of letters and numbers is poor. She struggles with scissors.

Communication

Her language skills emerged slowly and remain delayed. Articulation is particularly problematic.

Self-Care

Jackie was toilet-trained by 3.5 years of age but has occasional accidents, especially at night. She is not yet independent in many daily tasks, such as requiring some assistance with bathing and hygiene tasks and staying on task when getting dressed. She is working on shoe-tying.

Play and Leisure

Jackie enjoys pretend play with her friends around themes, such as being princesses. She has difficulty shifting to other themes, but she can follow the lead of her friends. She also likes stuffed animals.

SIPT and Clinical Observations

Jackie had been seen by an occupational therapist for nearly a year to work on motor coordination. She was progressing, but skill attainment was slow. Because of growing concerns that Jackie had limited awareness of her body movements, her parents, teacher, and the occupational therapist thought further evaluation would be useful. Jackie was administered the SIPT and Clinical Observations, and her mom and the teacher were asked to complete the SPM.

Completing the worksheet (Table 11-6) helped organize the available information from these evaluation tools. As seen in the worksheet, Jackie has a pattern of performance and observation scores that indicate poor somatosensory processing and difficulties with praxis. She has low scores on tests of tactile discrimination (e.g., GRA, FI, MFP) and tests reflecting knowledge of body movement in space (e.g., KIN, PPr, OPr, BMC, SWB). She shows low scores on all tests of praxis. Clinical observations indicate poor supine flexion, weak prone extension, difficulty with thumb and finger touching and diadokokinesia, and limited ideation abilities in play. Jackie also has difficulties with many aspects of vestibular function, which is not uncommon in children with somatodyspraxia. She shows poor postural control in poor static and dynamic balance (SWB; clinical observations) and weak prone extension. Further evidence of inadequate vestibular processing is seen with her depressed PRN.

Jackie's parents reported definite sensory responsivity concerns with heightened reactivity in auditory and tactile areas and poor registration in vestibular and proprioceptive areas. Interestingly, her teacher reported typical overall sensory responsiveness. Both parents and teacher reported some problems with social participation and planning and ideas.

Conclusion

Jackie is a sweet, social girl, identified as having speech and language delays and motor incoordination at 6 years of age. On further evaluation at 7 years of age, she shows evidence of SI difficulties, including poor somatosensory awareness and perception as well as poor vestibular perception. Her difficulties with SI are associated with problems in activities that involve ideation, sequencing, and the ability to follow unfamiliar instructions; thus, she is easily overwhelmed by complex and novel directions and tasks. These problems help explain her anxiety at being dropped off at school, her fine and gross motor clumsiness, and her delays in fine motor skill development, which interfere with her written communication. The mismatch between SPM scores at home and at school may be a

TABLE 11-6 Jackie's Completed Interpretation Worksheet

VISUAL	SCORE
Visual Spatial	
SV	–0.89
FG	–0.79
Visual Praxis	
DC	–2.09
CPR	–0.67
MAC	–2.14
Haptic Form and Space	
MFP	–2.04
GRA	–1.17
Observations	
Able to complete age-appropriate puzzles with help organizing	

VESTIBULAR	SCORE
Postural Control	
SWB	–2.18
Prone extension	Weak
Stability	Poor
Righting	Poor
Equilibrium	Poor
Vestibular-Ocular	
Low PRN	–1.63
Ocular stability	Mod
Head/neck/eye coordination	Poor
Observations	

SOMATOSENSORY	SCORE
Proprioception	
KIN	–3.00
SWB	–2.18
Poor body scheme	Yes
Observations (e.g., Finger/nose thumb/finger touching, diadokokinesis)	Poor
Tactile	
LTS	–0.05
GRA	–1.17
FI	–1.20
MFP	–2.04
Observations	

INTEROCEPTION/ SENSORY MODULATION	SCORE	
SPM results	Home	Scl
Visual	OK	OK
Hearing	SOR	OK
Touch (LTS)	SOR	OK
Body awareness	SUR	OK
Balance and motion	SUR	OK
Observations		
Arousal	Fluc	OK
Affect	OK	OK
Activity level	Hi	Hi
Attention	Can be poor at times	

BILATERAL INTEGRATION	SCORE
BMC	–1.20
SPr	–2.80
OPr	–0.99
GRA	–1.17
MFPII	–1.10
MAC	–2.14
Observations (e.g., skipping, jumping jacks)	Poor

PRAXIS	SCORE
PPr	–1.78
OPr	–1.46
PrVc	–1.45
(SPr)	–2.80
(BMC)	–1.20
Flexion	Poor
Observations (e.g., play)	Limited play schemes; poor ideation in play

RIGHT HEMISPHERE	SCORE
Low performance IQ	OK
High verbal IQ	
Poor visual spatial SV, FG, FI, DC	DC low
Significantly lower left-sided scores	
Low frustration tolerance	NO

LATERALITY	SCORE
SVCU	OK
PHU	
R/L differences	
Poor scores on directionality, reversals, inversions, jogs	
Observations	

PRAXIS ON VERBAL COMMAND	SCORE
PrVC (low)	–1.45
PRN (average to high)	–1.63
Poor sequencing	YES
Possible low scores on: OPr, SPr, BMC, SWB, DC	YES

LEFT HEMISPHERE	SCORE
High performance IQ	Not available
Low verbal IQ	
Poor sequencing	

result of the fatigue from working hard through the school day to accomplish tasks.

Recommendations

Jackie is eligible for occupational therapy as a related service on her individual educational plan (IEP); she has been receiving some but would benefit from a more intense program, focused on her sensory integrative needs. It is recommended that the IEP team include 1 hour of individual, direct occupational therapy services per week, in a setting with specialized therapy equipment, by a therapist with a background in SI intervention.

Sample Goals

1. Improved participation in daily routines: Jackie will complete familiar multistep a.m. or p.m. routine activities in a 10-minute period with no more than one adult assist on 4/5 opportunities. (Evidence of improved motor planning.)
2. Participation in playground activities: Jackie will demonstrate an improved ability to perform play activities, games, or dance routines involving sequences of action, completing them with 80% accuracy.

Accommodations

Accommodations in her daily routine will be helpful to assist her self-regulation, general arousal level, and attention.

- Mobile seating devices, such as a peanut ball, rocking chair, sit-n-move cushion, or therapy ball, may be used to increase vestibular and proprioceptive input throughout the day. Supported seating is preferable to floor sitting because of challenges with postural control.
- Her daily routine should include frequently scheduled activity or calisthenic breaks to provide vestibular and proprioceptive inputs.
- Prepare Jackie in advance for transitions and new circumstances, including where she needs to go, what will happen, what other people will be doing, what she is expected to do, how long it will last, and what happens when it is finished.

Summary and Conclusions

In order to interpret evaluation data related to SI and praxis, therapists must have expert knowledge of the critical role that sensation plays in supporting and guiding function as well as common patterns of SI deficits affecting individuals and populations. Although it is not always possible to use all assessment tools described for all individuals, in-depth knowledge of typical and atypical development relative to the SI constructs and patterns provides the basis for understanding the areas of performance that are affected and the recommendation for service.

We have presented the process of interpreting the results of an occupational therapy evaluation of SI. An important component of the process was to reframe presenting problems in terms that are easily understood by families and in keeping with the unique perspectives of occupational therapy and SI theory. We interpreted data by examining test scores for meaningful clusters. When clusters were identified, they formed the basis for reframing and planning intervention. In subsequent chapters, we discuss providing intervention using direct service (Chapter 12, The Art of Therapy, and Chapter 13, The Science of Intervention: Creating Direct Intervention from Theory, respectively) and consultation (Chapter 17, Using Sensory Integration Theory in Coaching). Interpretation of findings leads logically to recommendations for intervention as well as goal setting. These topics are addressed in more detail in Chapter 20 (Planning and Implementing Intervention Using Sensory Integration Theory) and Chapter 21 (Planning and Implementing Intervention: A Case Example of a Child with Autism), respectively.

Where Can I Find More?

Lane, S. J., Roley, S. S., & Champagne, T. (2013). Sensory integration and processing: Theory and applications to occupational performance. In B. Schell & G. Gillen (Eds.), *Willard and Spackman's occupational therapy* (12th ed., pp. 816–868). Philadelphia, PA: Lippincott Williams & Wilkins.

Parham, L. D., & Mailloux, Z. (2015). Sensory integration. In J. Case Smith & J. O'Brien (Eds.), *Occupational therapy for children and*

adolescents (pp. 258–303). St. Louis, MO: Elsevier Mosby.

Schaaf, R. C., Schoen, S. A., May-Benson, T. A., Parham, L. D., Lane, S. J., Smith Roley, S., & Mailloux, Z. (2015). State of the science: A roadmap for research in sensory integration. *American Journal of Occupational Therapy, 69.* 6906360010p1-p7. doi:10.5014/ajot.2015.019539

Schaaf, R., & Mailloux, Z. (2015). *A clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism.* Baltimore, MD: AOTA Press.

Schaaf, R. C., & Roley, S. S. (2006). *SI: Applying clinical reasoning to practice with diverse populations.* Austin, TX: ProEd, Inc.

References

Ayres, A. J. (1965). Patterns of perceptual–motor dysfunction in children: A factor analytic study. *Perceptual and Motor Skills, 20,* 335–368.

Ayres, A. J. (1966a). Interrelationships among perceptual–motor functions in children. *American Journal of Occupational Therapy, 20,* 68–71.

Ayres, A. J. (1966b). Interrelationships among perceptual–motor functions in children. *American Journal of Occupational Therapy, 20,* 288–292.

Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities, 2,* 160.

Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. *American Journal of Occupational Therapy, 25,* 329–334.

Ayres, A. J. (1972). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy, 26,* 13–18.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy, 31,* 362–366.

Ayres, A. J. (1989). *The Sensory Integration and Praxis Tests manual.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (2005). *Sensory integration and the child, 25th anniversary edition.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J., Mailloux, Z., & Wendler, C. L. (1987). Developmental dyspraxia: Is it a unitary function? *Occupational Therapy Journal of Research, 7,* 93–110.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, 47*(6), 591–601.

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and Young Children, 9*(4), 23–35.

Dunn, W. (2014). *Sensory Profile™ 2.* San Antonio, TX: Pearson.

Dunn, W., & Brown, C. (1997). Factor analysis on the Sensory Profile from a national sample of children without disabilities. *American Journal of Occupational Therapy, 51,* 490–495.

Exner, C. E. (1992). In-hand manipulation skills. In J. Case-Smith & C. Pehoski (Eds.), *Development of hand skills in the child* (pp. 35–46). Bethesda, MD: American Occupational Therapy Association.

Exner, C. E. (2001). In-hand manipulation skills. In J. Case-Smith (Ed.), *Occupational therapy for children* (4th ed., pp. 289–328). Rockville, MD: Elsevier Inc.

Fisher, A. G. (1989). Objective measurement of the quality of response during two equilibrium tests. *Physical and Occupational Therapy in Pediatrics, 9,* 57–78.

Kirby, A., Dickie, V., & Baranek, G. (2015). Sensory experiences of children with autism spectrum disorder: In their own words. *Autism, 19*(3), 316–326.

Kirby, A. V., Little, L., Schultz, B., & Baranek, G. T. (2015). Observational characterization of sensory interests, repetitions, and seeking behaviors. *American Journal of Occupational Therapy, 69,* 6903220010p1-6903220010p9. doi:10.5014/ajot.2015.015081

Koester, A. C., Mailloux, Z., Coleman, G. G., Mori, A. B., Paul, S. M., Blanche, E., . . . Cermak, S. A. (2014). Sensory integration functions of children with cochlear implants. *American Journal of Occupational Therapy, 68,* 562–569. doi:10.5014/ajot.2014.012187

Lane, A. E., Dennis, S. J., & Geraghty, M. E. (2011). Brief report: Further evidence of sensory subtypes in autism. *Journal of Autism and Developmental Disorders, 41,* 826–831.

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of children with autism spectrum disorder by sensory subtype: A case for sensory-based phenotypes. *Autism Research, 7,* 322–333. doi:10.1002/aur.1368

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders, 40,* 112–122.

Lane, S. J., Roley, S. S., & Champagne, T. (2013). Sensory integration and processing: Theory and applications to occupational performance. In B. Schell & G. Gillen (Eds.), *Willard and Spackman's occupational therapy* (12th ed., pp. 816–868). Philadelphia, PA: Lippincott Williams & Wilkins.

Mailloux, Z., Mulligan, S., Roley, S. S., Blanche, E., Cermak, S., Coleman, G. G., . . . Lane, C. J. (2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy, 65,* 143–151.

Mulligan, S. (1996). An analysis of score patterns of children with attention disorders on the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy, 50,* 647–654.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy, 52,* 819–828. doi:10.5014/ajot.52.10.819

Parham, L. D., Ecker, C., Miller-Kuhaneck, H., Henry, D. A., & Glennon, T. J. (2007). *Sensory Processing Measure (SPM): Manual.* Los Angeles, CA: Western Psychological Services.

Parham, L. D., & Mailloux, Z. (2015). Sensory integration. In J. Case Smith & J. O'Brien (Eds.), *Occupational therapy for children and adolescents* (pp. 258–303). St. Louis, MO: Elsevier Mosby.

Schaaf, R., & Mailloux, Z. (2015). *A clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism.* Baltimore, MD: AOTA Press.

Siaperas, P., Ring, H. A., McAllister, C. J., Henderson, S., Barnett, A., Watson, P., & Holland, A. J. (2012). Atypical movement performance and sensory integration in Asperger's syndrome. *Journal of Autism and Developmental Disorders, 42,* 718–725.

Smith Roley, S., Mailloux, Z., Parham, L. D., Schaaf, R. C., Lane, C. J., & Cermak, S. (2015). Sensory Integration and Praxis patterns in children with autism. *American Journal of Occupational Therapy, 69,* 1–8. doi:10.5014/ajot.2015.012476

Su, C., & Parham, L. D. (2014). Validity of sensory systems as distinct constructs. *American Journal of Occupational Therapy, 68(*5), 546–554.

van Jaarsveld, A., Mailloux, Z., Roley, S. S., & Raubenheimer, J. (2014). Patterns of sensory integration dysfunction in children from South Africa. *South African Journal of Occupational Therapy, 44*(2), 2–6.

Wilson, B., Pollock, N., Kaplan, B. J., & Law, M. (2000). *Clinical observations of motor and postural skills.* Framingham, MA: Therapro.

PART

IV

Intervention

CHAPTER

12

The Art of Therapy

Anita C. Bundy, ScD, OT/L, FAOTA ■ Colleen Hacker, MS, OTR

The kind of involvement necessary to achieve the state wherein the child becomes effectively self-directing within the structure set by the therapist cannot be commanded; it must be elicited. Therein lies the art of therapy.

—Ayres, 1972, p. 259

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Identify components that facilitate the art of therapy, including therapeutic use of self.
- ✔ Discuss how visual, auditory, tactile, proprioceptive, and vestibular sensory input can be used to optimize the effectiveness of an intervention session for a particular child.
- ✔ Define play, and describe essential components of play, including inner drive, internal control, freedom from the constraints of reality, and framing.

Introduction

In the varied topography of professional practice, there is a high, hard ground where practitioners can make effective use of research-based theory and technique, and there is a swampy lowland where situations are confusing "messes" incapable of technical solution (Schön, 1983, p. 42).

The children that we see in sensory integrative therapy often have lives that are mired in muck. Even the simplest everyday challenges seem too difficult. The muck is a part of what makes them interesting and what makes their intervention so important. As Schön (1983, p. 42) reminded us, "problems of the swamp are those of greatest concern." Schön went on to suggest that some therapists deliberately involve themselves in the messy, but crucially important, problems of the swamp. Those highly skilled therapists, who succeed time after time in these most difficult of situations, rely heavily on art. Therapy with such children also commonly reflects the swampy lowland. An hour-long session where we try to stretch children to the limits of their abilities can easily take a dozen unexpected twists and turns. Very rarely does any therapy session follow the high, hard ground (i.e., the rules of theory). In fact, fully half of the Fidelity Measure (Parham et al., 2011), which operationally defines sensory integrative therapy, reflects art: collaboration in activity choice, tailoring activity to present a just-right challenge, ensuring that activities are successful, supporting the child's intrinsic motivations to play, and establishing a therapeutic alliance (see also Chapter 14, Distilling Sensory Integration Theory for Use: Making Sense of the Complexity).

Artful practitioners respond to complexity in what seems to be simple ways and without disrupting the flow. They make therapy look easy, even with the most difficult child and in the most difficult situation. The therapist approaches each session as though it were unique. That is not to say that the therapist acts without the benefit of theory or prior experience. But she is not looking to solve a problem by simply rolling out something she has rolled out previously either. Rather, in each therapy session, the actions and interactions of an artful therapist change the situation repeatedly. The therapist then considers how happy she is with each outcome and what those outcomes have taught her. Schön described this way of approaching therapy as a kind of reflective conversation**: reflection-in-action.** The therapist "speaks"; the situation "talks back." The therapist listens, and as she appreciates what she hears, she reframes the situation once again. "The process spirals through stages of appreciation, action, and reappreciation. The unique and uncertain situation comes to be understood through the attempt to change it, and changed through the attempt to understand it" (Schön, 1983, p. 132).

Purpose and Scope

This chapter has two main sections. After meeting Phoebe, a 4½-year-old early in her therapy, we will be voyeurs on a particularly artful session—one in which, despite the murky situation, the therapist, at one point, reflected, "I was feeling pleased at how the session was unfolding." We view the session as a whole and then de-construct it to examine the therapist's reflections. In the second section, we focus on the therapist as playmate and promoter of play and we define sensory integrative therapy as a special form of play and examine the characteristics of this subset of play.

CASE STUDY ▪ PHOEBE

Phoebe is an engaging blonde, tall for her age but otherwise petite. Her overall goal was to be ready for kindergarten in 6 months. Her family's concerns included Phoebe's persistent anxiety. They described her as clingy, cautious, lacking confidence, and withdrawn in new or unfamiliar settings. Phoebe also experienced significant challenges with gross motor skills. These concerns, coupled with delays in language and difficulties playing and interacting with peers, resulted in a referral to occupational therapy. In this first session, narrated by Phoebe's therapist, the focus is on minimizing gravitational insecurity and improving postural-ocular responses.

The Session: As Told by the Therapist

Even given my observations of Phoebe during the assessment, and information gathered during my interview with her parents, I was still a little surprised at the *degree* of anxiety that Phoebe experienced relative to movement and at the lengths she went to in an attempt to cope. Her immediate "go-tos" were to get quite bossy and demanding. Her anxiety and feelings of being overwhelmed led to a disconnect from her already poor pragmatic language, making the communication dance with her even trickier than it had been during the assessment. After the first 5 minutes of Phoebe's first intervention session, I knew I had to use several resources to draw her in and empower her to participate in the activities most likely to help her progress.

I start all my therapy sessions expecting that the child "can" and "will." My expectations for Phoebe were no less. My previous reflections on her needs, based in theory, supported using vestibular-proprioceptive-based activities to help move her through some of the gravitational insecurity. Balancing the just-right amount of vestibular with the just-right amount of proprioception was an important strategy to promote her ability to modulate sensation. Gaining active participation and trust in me and in the process was even more important. Phoebe's first session began gently. I followed her lead as to what toys interested her most and we began to build a story around those toys. Following the child's lead in the early moments not only gains trust but also gives the session a foundation. If I went in thinking only about the types of sensation that should help her to regulate and organize herself, I would likely lose her. But when we construct a story together and then layer in activity and sensation based in theory, the session is much more likely to succeed.

To help Phoebe know that I was "on her team," I provided lots of choices early on. I did not ask her to "repair" her language. Her meanings were clear even if her words were not precise. We were, in the early moments, just gaining a sense of each other and how we would work together. I was quick to scaffold her and not leave her hanging too long in spaces created by deficits in language and processing. I did not want to leave her too exposed too early. She would have trouble trusting me if I did. Though we began, literally, with our feet firmly planted on the floor and slightly uneven surfaces the only challenge to posture, I moved forward to bigger challenges within 15 minutes. Phoebe and I had established a partnership by this time and I knew that whatever cracks appeared in the session, we would be able to repair them. In moving forward to bigger challenges, Phoebe's language deficits worked in my favor. She agreed before she quite understood and then we were in it together. I put my efforts into moving her through to the other side (Fig. 12-1). Of course, I did not just ask her to climb the ladder; I wove the ladder into the story of the session. Phoebe was halfway up the ladder before her anxiety kicked in. Then she felt a little paralyzed. I stayed immediately behind to lessen her fear of falling. I pushed down on her hips, hoping this input would help to keep her calm and able to problem-solve. Although her mother and a student occupational therapist were present in the room, it felt like just me and Phoebe. I whispered encouragement and more of the "plot line" of the session. This created a sense of complicity. She climbed the ladder to the platform on top, moving through her fear.

Once up, she had to come down. I gave her the power to choose how. Moving down is often more frightening than moving up, so I wanted her to feel in control. I kept her actively engaged in problem-solving and transmitted my belief that she could work this problem out. She seemed to feel my belief in her, which helped her to regulate in what would otherwise have been a daunting situation. She directed me to build the just-right stack of pillows so that she could get down from the platform (which was 6 feet [2 meters] high! See Fig. 12-2).

FIGURE 12-1 A foundation of trust, close proximity, and weaving "climbing the ladder" into the story unfolding in our session helped overcome Phoebe's anxiety initially. *Photo courtesy of Colleen Hacker.*

Phoebe initially blanched as she climbed into the pillow stack and began to slip through the pillows. My vocalizations matched her slow-motion descent and helped her regulate, perceiving the reality of the event rather than the limbic "fear." She was able to anticipate the slow descent, and her anxiety was staved off once again (Fig. 12-3). Even so, it was important to acknowledge that she looked a little worried and check in with her about her current state. She was okay and ready to try again! I was feeling pleased at how the session was unfolding. I had incorporated a fair amount of movement and resulting vestibular sensation into the activity while helping Phoebe remain regulated. I purposefully mediated her anxiety through therapeutic use of self and judicious use of proprioception and deep pressure.

We were now halfway through the session and I wanted to up the ante. My expectations of what Phoebe could manage had increased. I continued to embed the story that we had

FIGURE 12-2 At Phoebe's instruction, I built up the stack of pillows that she would use as a landing pad to get down from the loft. Giving her control over this strategy was crucial to maintaining trust while at the same time empowering Phoebe to use her own problem-solving. *Photo courtesy of Colleen Hacker.*

FIGURE 12-3 As Phoebe moved from the loft to the stack of pillows, she did so slowly and with great caution. I stayed close and matched her slow movements with slower vocalizations to help her regulate. *Photo courtesy of Colleen Hacker.*

created early in the session into each new activity. I added a moving surface, very low to the ground (a platform swing), and initially gave Phoebe complete control over the type and speed of movement (Fig. 12-4). I also added the possibility of "danger." When Phoebe lost her balance and stepped off the "slippery rock" (a foam step placed on top of a mat), there could be a "surprise." Surprising her without setting the stage would have blindsided her and undone the trust we had built. Instead, I helped her anticipate through foreshadowing. I wanted the level of her arousal to go up. I wanted her to feel a little bit worried. AND I wanted her to handle it. When Phoebe lost her balance and stepped off the rock, the promised "dangerous surprise" occurred—but in slow motion. I gave her lots of time to know I was coming. I kept my body purposefully small and made sure that I was not looming over her in a threatening way. I kept her face-to-face as we wrestled in the pillows. I never wanted her to feel overpowered. She was always on top. As we moved, I narrated each action, feeling like a sports commentator; this kept her in the loop and prevented her from overloading. I knew her ability to modulate would improve only if we could broaden the sensory experiences she could manage. I had to build the experiences in a safe way, with just enough intensity and duration that she could escalate, contain it, and recover. If I went too far, I would risk the relationship and my ability to help Phoebe interact in an adaptive manner.

After all this excitement, I wanted to provide more resistive input (proprioception) to help Phoebe mediate her own arousal effectively. I wanted her close to me in order that she could draw on the trust we had built, so I used my own body as the source of the resistance: Phoebe got "stuck" on my lap. I played dumb as to how this could have happened and made it clear through my narration that I was trying to be helpful to Phoebe in her attempts to free herself. This increased the sense of complicity. We were working together, not in opposition. Phoebe's confidence continued to build. I now wanted Phoebe to direct a situation that incorporated a little more intensity and risk taking. We went back to the pillow mountain and "raced" to the top once again to retrieve a desired toy that was part of the game. I was less gentle with Phoebe now, pushing against her as we struggled up the pillows. She responded in kind. She seemed sure she could win and several times announced "I'm doing it." This was no small feat from a little girl who, 45 minutes earlier, had been fearful of stepping off onto the same pillows. She was now tumbling with abandon on the pile of pillows, trying to "win." She did win, of course. It was too early in our relationship to impose the idea of losing. However, I am not a pushover! Phoebe worked for her win, gaining empowerment as she went.

FIGURE 12-4 Providing decision-making control to Phoebe allowed us to move to a more challenging activity. Phoebe sits on a platform swing, suspended close to the ground. Phoebe had full control over speed, direction, type, and intensity of movement. *Photo courtesy of Colleen Hacker.*

As the end of the session drew near, I wanted to create a bigger movement demand for Phoebe. She readily climbed onto the platform swing but immediately began to "boss," attempting to control the degree of movement allowed. We negotiated rotary vs. linear, one-finger vs. two-finger pushes, and so on. Occasionally, I threw in a surprise quick jolt. She was upset by my change in the routine. I immediately mirrored her upset face followed by a deep, regulating breath. Through my mirroring, she was "heard." Because she was heard, she attuned to me, and my breathing helped her breathe deeply and regulate. She did not like the jolting movements that I continued to introduce sporadically, but after the first one, she had no more overt fear responses. I had taken her a little "over the edge" but also provided strategies and space for her to recover—and recover quickly. Time for the session to close. I felt like Phoebe had taken important steps. I wanted her to hang on to that information. I wanted to mark it for her and help her retell it. So together, we reconstructed the sequence of the session and all of Phoebe's accomplishments. We did not leave out the fact that she was sometimes worried. We did include the resolution to each of those worries. We used adjectives like "awesome," "incredible," "brave," and "strong" to describe Phoebe (Fig. 12-5). Her smile at the end of the session was exactly what I'd been working for. It was the smile that says, "This is about me. I did it. I can do it. I own it."

Phoebe continued in therapy for approximately 18 months. By the time she was in first grade, she no longer experienced the challenges that had brought her to therapy initially. Her language processing was up to speed. She was excelling academically. She was no longer hesitant on playgrounds, though she still exercised personal (and appropriate) judgment around risk taking.

HERE'S THE POINT

- Artful therapists constantly evaluate a child's behavior and responses throughout intervention sessions so that they can effectively adjust their approaches and activities to build a trusting relationship and to ensure both they and the children are having fun.
- Through active reflection, thoughtful application, and readjustments of sensory experiences, artful therapists optimize the child's level of arousal, motivation, and readiness to engage in active play, and successfully meet challenges.

FIGURE 12-5 As our session came to a close, Phoebe and I paused to reflect on what had been accomplished. Although acknowledging that she was occasionally a bit worried, we celebrated her ability to problem-solve and to conquer. *Photo courtesy of Colleen Hacker.*

The Artful Therapist: A Good Playmate

What made this therapist a good playmate? Skillful playmates have at least three traits:

1. They read the cues of the child accurately and respond with great skill.
2. They give unambiguous and appropriate cues as to how the child should act toward them in play.
3. They play as equals—engaged in give-and-take and not dominating the play.

In addition to being a playmate, the therapist assumes a caregiving role. Within the session, the therapist takes on a persona that says, "This play and the things that you value are important." They set clear, but flexible, rules. They ensure that the child is physically and emotionally safe (Skard & Bundy, 2008).

During the session, Phoebe's therapist wore all these hats—changing them without hesitation. As a playmate, she read Phoebe's cues vigilantly; she gave out exaggerated cues, changing her actions and persona as needed. She entered the play enthusiastically. As a caregiver, she became guide, narrator, empathic supporter, and cheerleader—without missing a beat. In all these roles, she was convincing, knowing that Phoebe would sense artifice or discomfort. Alongside her roles as playmate and caregiver, Phoebe's therapist also paid close attention to sensory integrative theory, considering less-than-obvious aspects of sensation that affect the outcome of the session. Even before she began the session, she reflected on what she had learned from assessment and the way that she had framed the problem. As Schön (1983) suggested, she asked, "Can I solve the problem I have set?" And, as she went along, she reflected in action. "Do I like what I get as I attempt to solve the problem?" Knowing that Phoebe felt anxious, especially in the context of movement and when she was not completely in control, the therapist asked repeatedly, "How is *this* sensation (and this activity) affecting and interacting with Phoebe's emotions?" And, as she finished, it is not difficult to imagine that Phoebe's therapist asked herself, as Schön suggested, "Have I made the situation coherent? Have I made it congruent with my fundamental values and with sensory integration theory? Have I kept the inquiry moving?" (p. 133).

Perhaps more important even than the equipment or the activities is the intensity of the sensation created by the interaction between therapist and child. For the child, sensation interweaves with emotional state, yielding the actions and behaviors that the therapist sees. A thoughtful approach to the sensations embedded in the interaction is, therefore, part of the art of therapy. **The therapeutic use of self,** in this case the ability to nuance sensation embedded within the interaction, creates an environment that promotes change. The therapist responds mindfully to sensory events in order to "guide" the child's reaction, helping the child "mirror" a mediated response. We think of this as "co-regulation." In mirroring the therapist's regulated state, the child comes to associate sensation with positive emotions. There are many ways for the therapist to nuance the sensation, partner empathetically with the child, and sustain the flow of the session. In the section that follows, we hope to help readers reflect on the decisions that Phoebe's therapist made (and that readers make) about sensation that are embedded in the therapeutic interaction—beyond the enhanced sensation that is inherent to sensory integration (SI) theory.

Vision

Assuming the perspective of a child, consider the visual input created by the therapist. This is more than physical appearance; it is about the visual "feel" created by all aspects of the therapist's presence. A therapist can communicate with a child without saying a word, through subtle facial expressions. The therapist holds expressions long enough for a child slow to process nonverbal information to read them. The therapist can also mirror the child's facial expressions. If the child seems to feel confronted by too much face-to-face contact, the therapist can move subtly in and out of the child's visual field. All these strategies support a co-regulated, mutually engaging, collaborative treatment experience. In reflecting in and on action, the therapist can ask, "Did my body language look inviting or imposing? Did I look relaxed and open to ideas? Was my facial expression suitably warm and engaging, or did it feel remote and disinterested? How did the impact of the size differential between me and the child inhibit or facilitate the therapeutic partnership and the child's taking control? Did my actions seem big and looming? Or did I minimize the size difference and, thus, the power differential?" Phoebe's therapist made a conscious decision to diminish her size—walking on her knees to "surprise" Phoebe. She used exaggerated facial expressions so that Phoebe knew her fears were "heard" and to help her co-regulate.

Auditory

The auditory environment is complex and has a marked effect on the tone of a session. The therapist's voice is an important aspect of the auditory environment. Volume, intonation, and prosody (i.e., tune and rhythm of speech) all contribute. In varying volume, a therapist can draw the child into partnership. Changes in volume can be powerful. Sometimes a whisper denoting collaboration and conspiracy (i.e., "it's you and me") is more effective than a shout—as it was with Phoebe. Tone and prosody also help a child understand which "hat" the therapist is wearing. A just-right amount of novelty and contrast facilitates attention to a task. A therapist's language, although not purely auditory input, also contributes to the just-right challenge and supports regulation. Words are powerful, and children readily associate them with emotion. The therapist's words must invite the child toward mastering rather than impart judgment. Sometimes simply changing one word can change the whole message. "Can you think of *another* way to do that?" is far less judgmental than "Can you think of a *better* way to do that?" Quantity of language is also important; less definitely can be more. Sometimes a simple "hmmmm" or raised eyebrow communicates more than an in-depth explanation. Pace and rhythm of language are also important. Slow rhythmic vocalizations or verbalizations promote calming, timing, and sequencing within an activity. Changes to rhythm promote alertness and can add an element of surprise to an activity. Consider how Phoebe's therapist used all aspects of language to help Phoebe regulate emotions.

Tactile

Touch can feel supportive, empowering, regulating, or punitive. A therapist can impart feelings of nurturing by cocooning, as Phoebe's therapist did on the ladder and later in "trapping" Phoebe on her lap, or empowering, with a gentle tap on the shoulder. A child inevitably interprets touch as reflecting the intent of the person administering it. Thus, the therapist must continually reflect on the effects of touch on arousal and well-being. Touch must always be in line with the recipient's sensory profile. A child with challenges modulating sensation may interpret even incidental touch, from a therapist or equipment, as dangerous and become hypervigilant rather than engaging in the play.

Proprioception

Children often seem driven to generate proprioception. However, although intrinsically motivated, sensory seeking does not always yield improved organization. Further, proprioception can be either calming or alerting. Thus, the artful therapist monitors both the quantity and quality of proprioception provided during a session. Endless "heavy work" opportunities are desired only if they support engagement and function. Phoebe's therapist used her own arms and legs to "trap" Phoebe on her lap. Extricating herself from the cocoon created by the therapist's body yielded proprioception as Phoebe pushed against the therapist's arms and legs. Because she used her own body, the therapist could feel Phoebe's resistance and adjust her own body as needed to ensure a just-right amount of proprioception and also a just-right challenge.

Vestibular

There are many more considerations to providing vestibular sensation than simply choosing a swing that provides the optimal kind of movement to promote posture or motor planning. The power of vestibular input means that it is particularly important for the therapist to help the child maintain a "just right" arousal state while challenging movement. The therapist might move with the child through space, serving as a container (e.g., the therapist rolling together with Phoebe down the mountain of pillows). The therapist might also be the agent that helps control speed, direction, and rhythmicity of vestibular input as Phoebe's therapist did with the platform swing. The therapist's own movements must be graded in order to give the intended message and influence the child's level of arousal in a desired way. Rhythmicity and timing contribute to predictability and assist the child to anticipate. Although surprise can be highly motivating for some children, the therapist must grade the degree of predictability and be mindful of the amount of surprise that a child can manage—as Phoebe's therapist did. Successful therapy is about pushing against a child's limits in order to expand possibility; however, each child has limits and an optimal range of tolerance and the therapist must reflect on these continually.

HERE'S THE POINT

- Artful therapists have mastered ways of applying "therapeutic use of self" so that children feel and are emotionally and physically safe.
- They read the cues of children accurately and respond skillfully by providing unambiguous and appropriate cues as to how children should act toward them in play, and they engage as equal play partners.
- Artful therapists consider how visual, vestibular, tactile, proprioceptive, and auditory sensory input can be tailored to meet the child's sensory needs, enhance play skills, and address the child's therapy goals throughout intervention sessions.

Play as the Basis of Sensory Integrative Therapy

Therapy sessions comprise a special kind of play between a child and an adult playmate in which the child is afforded opportunities for enhanced tactile, vestibular, and proprioceptive sensation. But how does a therapist ensure that a session is playful? What *is* play? In this section, we define play and examine each of the elements. In defining play, we draw from Neumann (1971), an educator, and Bateson (1972), an anthropologist. Finally, we firmly embed sensory integrative therapy in play, suggesting that fully half of the process elements that Parham and colleagues (2011) described as essential to SI are, in fact, elements of play.

Defining Play

Neumann (1971) described three criteria for play: relative internal control, intrinsic motivation, and freedom to suspend reality. She considered that transactions containing all three fell toward the play end of a play–non-play continuum. In Figure 12-6, we illustrate Neumann's conceptualization of the three elements of play contained within a picture frame. The notion of the frame came from Bateson (1972) who described the cues that set play apart from real life as similar to the way a picture frame separates a painting from the wall. We, thus, propose the following definition of play:

> **Play** is a transaction that is relatively intrinsically motivated, relatively internally controlled, free of many of the unnecessary constraints of objective reality, and that is demarcated by clear cues, separating play from the rest of everyday life (i.e., framed clearly as play).

Play that comprises sensory integrative therapy occurs between a child receiving the therapy and an adult therapist playmate. For therapy to be effective, both must be playing; that is, both must feel relative intrinsic motivation and internal control and both must be free to suspend some aspects of reality. However, in addition to playing, the therapist is also assuming a presence that says, "This is play and play is important"; by framing and reframing the problems that constitute the session and judging the extent to which the solutions are congruent with theory and experience, the therapist is reflecting in action.

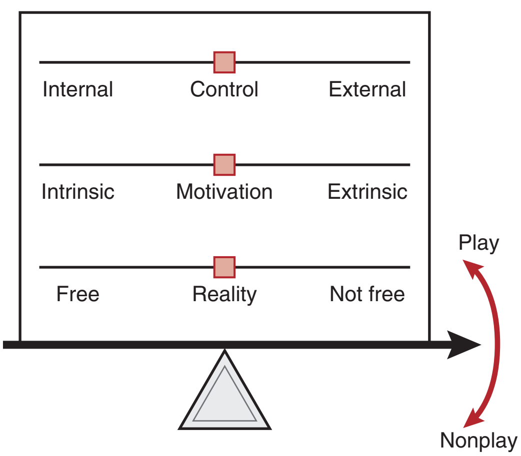

FIGURE 12-6 The elements of play.

Play Element 1: Relative Intrinsic Motivation

Intrinsically motivated activities are done for their own sake—for the pleasure of engaging in them. A child in therapy is not engaged in the activities to reduce the sensory integrative dysfunction; because someone asked the child to do them; or to gain any external reward—even winning (Ryan & Deci, 2000a, 2000b). Nonetheless, winning is sometimes important—as it was for Phoebe climbing the pillow mountain. **Intrinsic motivation** is almost universally acknowledged as an essential element of play (e.g., Rubin, Fein, & Vandenberg, 1983; Sutton-Smith, 1997). But that does not mean a child or a therapist has *no* extrinsic motivation in the session. Children, for example, often enjoy accruing points when they hit a target. However, the fun of engaging in the activity—not the points—is the most important part. Even if there were no points, the child would still enjoy hitting the target. Therapists are motivated by minimizing the discrepancies that confront the child with whom they are working—an extrinsic motivator—but for the time they are engaged in a therapy session, intrinsic motivators are also very important. The therapist must be having fun, too; if a therapist is not playing, the child will not be playing.

Activities are intrinsically motivating for different reasons. Numerous authors (e.g., Ayres, 1972; Deci & Ryan, 2000; Neumann, 1971; White, 1959) emphasized the link between motivation and inner drive or mastery. Relatedness or social interaction is another common motivator (e.g., Csikszentmihayli, 1975a; Deci & Ryan, 2000), as is pure sensation (Caillois, 1979). Sources of intrinsic motivation vary from person to person (Csikszentmihayli, 1975a). We seek to co-create activities that capture the motivations of both child and therapist. Phoebe was motivated by the story she had co-created with the therapist, a giant stuffed snake that she carried with her in all the activities, and the sense of accomplishment and relatedness she shared with the therapist. The therapist too was intrinsically motivated to engage in the play acting and silliness that characterized the activities. When the therapist and child are intrinsically motivated, they can become totally involved in the activities. Csikszentmihayli (1975a, 1975b, 1979, 1990) referred to this involvement as "flow." In studying thousands of people who described flow experiences, Csikszentmihayli uncovered traits of activities that enable flow, including clear, unambiguous feedback that is a part of the activity. Clear, immediate, unambiguous feedback is inherent to activities used in sensory integrative therapy. Children know immediately if they have hit a target or jumped to the desired spot. There is little, if any, need for the therapist to comment on success (Ayres, 1972). Phoebe clearly knew when she made it to the top or the bottom of "pillow mountain" and when she succeeded (or failed) at maintaining her balance on the "slippery rocks."

Persistence, even in the face of significant obstacles or challenges, is another sign that a child is intrinsically motivated. Children repeat activities that present a "just-right challenge" just as Phoebe required only a few activities to become totally engaged for the hour-long session. Therapists sometimes feel compelled to carry out several activities in a session; however, interrupting an activity in which a child is totally engaged is very disruptive to flow. And, learning a new skill can require thousands of repetitions. There are no "rules" about how many activities should be done in a session or how long each activity should last, but a small number of activities with seamless transitions is a mark of an artful session. Some activities pull for enthusiasm, exuberance, and manifest joy, which may be signs of intrinsic motivation. But sometimes a child is too engrossed to exhibit laughing, smiling, or other signs commonly associated with "fun." Much can be learned by keeping track of activities in which children become totally involved. Careful analysis of such activities yields important information about the sources of the particular child's intrinsic motivation.

Finding Inner Drive

Ayres (1972) wrote that the ultimate goal of sensory integrative therapy is a child who directs his or her actions meaningfully and with satisfaction. Because sensory integrative therapy is fun and seems to tap a common source of motivation, children generally engage readily. However, occasionally, a child balks, as Phoebe did, at activities that involve skilled movements or enhanced sensation. Then, especially, we endeavor, as Phoebe's therapist did, to find that child's **inner drive.** In our experience, "lack of motivation" usually means one of two things:

- The activity is too difficult or the child *believes* it is too difficult.
- The child's level of arousal is not optimal.

When an activity is too difficult or a child believes it is, the therapist modifies the demands or gives the child additional support. Phoebe thought several of the activities were too hard, and the therapist negotiated and enticed in a playful way. The therapist supported Phoebe from behind as she climbed the ladder. She offered a choice between one- and two-finger pushes on the platform swing. She kept up a running story line starring the large stuffed snake. Enticing Phoebe or any child to attempt a task is not about entering into a "power struggle." The purpose of enticing Phoebe to continue was to help her discover new skills and how capable she really was, not for the therapist to be in control. If children have trouble becoming completely engaged in an activity, it may be because their level of arousal is not optimal. Some children whose arousal level is too high seek or need protected space and calming activities (e.g., deep pressure or oral motor activities). Phoebe's therapist described her as anxious and fearful, suggesting her level of arousal was too high. Thus, her therapist engaged her in several activities with calming components. But she did not simply seek to calm her. As the therapist said, "I had taken her a little 'over the edge' but provided strategies and space for her to recover—and recover quickly."

Other children seem to need intense sensation to attain an optimal level of arousal. When engaged in activity that provides intense vestibular and proprioceptive sensation, they come "alive." Another child, Emily, showed signs of tactile defensiveness, especially with regard to clothing. Wanting to make Emily's intervention as efficient as possible, her therapist created activities that provided a lot of enhanced tactile sensation. Emily dug in a ball pit, crawled through a large stockinette tunnel, and played in shaving cream with her hands and feet. But something did not seem quite right; the indicators that Emily was totally engaged were just not present. When her therapist decided to take another tack, things changed dramatically. Emily chose to stand on the glider. The therapist created a "storm" and gave Emily a rough ride. Periodically, "whales" (i.e., therapy balls) swam underneath the swing, causing it to move in unexpected ways. Emily became more animated, directing the therapist and altering the activity in subtle ways. Although Emily's tactile defensiveness suggested her level of arousal was too high, the therapist soon learned that appearances can be deceiving. Therapists must constantly be aware that therapy is based on hypotheses; we are constantly looking for evidence that the hypothesis is incorrect and that we should alter our approach.

Play Element 2: Relative Internal Control

Neumann (1971) believed that relative **internal control** is the most important element of play. Children who feel internally controlled can act on their motivations by determining how to play. They are free to suspend some constraints of reality by transforming objects or themselves into something different or by bending some of the usual rules. Clearly, relative internal control is a critical aspect of play.

In 1988, Jane Koomar and Elise Holloway made a videotape of Jean Ayres involved in therapy with an almost 4-year-old child named Ray. The account of this session, drawn from the preface of the second edition of *Sensory Integration: Theory and Practice* (Bundy & Lane, 2002), is an excellent example of Jean Ayres, a master therapist, whose style was reserved and step-back, giving control to a child. The session began with Ray sitting inside a tire tube atop a platform swing, pulling on handles to make it move. Within a few moments, Ray held his arms out to Jean using the age-old gesture that means, "Pick me up." The overall impression was of a very young child. Jean, however, did not pick Ray up. Instead, she showed him where to place his leg and facilitated his active movement. In effect, she nonverbally said, "You do it yourself. I'm here to help."

Jean and Ray moved from one activity to another. Each time, he tried to get her to "rescue him" and each time she gently, firmly, and nonverbally insisted that he take control. Ray got on a "horse swing" suspended from the ceiling by two points, but it was too great a challenge to his poorly developed postural mechanism and he tried to throw himself off onto the mat below. Jean gently placed his hands back on the horse and held it to make it more stable. "Give it a good try," she seemed to be saying. After a few moments, she helped him get off by facilitating his movements again. Within 20 minutes, Ray had gotten on and off no fewer than six pieces of equipment. He seemed unable to get really involved with any of the equipment for more than a few moments. Jean followed his lead—always facilitating rather than doing for him. At one point, Ray stood on a vibrating platform and Jean offered to brush him using a soft, flat paintbrush, but Ray said, "No." And something about the way he said it suggested that he was taking control. Although it had once seemed that the session might never get underway (which I, as an experienced practitioner, found oddly comforting), that was no longer the case. A remarkable transformation was taking place: Ray shed his babyish ways before my eyes.

Ray's growth began surreptitiously but accelerated. He got involved in a game in which he drove a pretend truck along a makeshift road to deliver packages to Teresa, the therapist assisting Jean. In his actions and limited words, Ray became a deliveryman. And the game continued for 15 minutes or more with Ray becoming more and more assertive. At one point, when Teresa told Ray that he had room for only two packages, Ray screeched, "No, no, no, no!" at the top of his lungs. A sturdy truck driver had replaced the passive child who had begun the session.

Balancing Freedom with Structure

Because a child feels in control does not mean that therapy lacks structure. Ayres (1972) wrote,

> Free play does not inevitably, in itself, further sensory integration, but too rigid structure will inhibit the manifestation of potential. . . . Structure may push the child further toward the therapeutic objective than he can reach alone but too much will defeat its purpose. (p. 259)

Sensory integrative therapy is a special kind of play. To play, a child must *feel* in control. But, because a child feels in control does not mean therapy is chaotic. Although children are encouraged to initiate and express preferences and interests, the therapist alters the activities and the challenge both to help the child succeed and to be sure the intervention promotes increasingly complex adaptive behaviors. Had Phoebe been left on her own to decide exactly what to do and how to do it, she might have asked the therapist to read her a story. Instead, Phoebe and the therapist acted out a story that they had co-created. The story involved climbing a "dangerous mountain" and coming back down again. It involved being on a boat and rescuing objects from the sea and stepping across "slippery rocks" without falling in the water. The story required that Phoebe be the actor. The therapist, as supporting actor, coached Phoebe through physical and verbal prompts as well as slight alterations that served to scaffold (Ayres, 1972; Dunkerley, Tickle-Degnen, & Coster, 1997; Tickle-Degnen & Coster, 1995). The art was in the balance between freedom and structure.

Play Element 3: Freedom from Some Constraints of Reality

In play, children feel free to transform themselves, and activities, into anything they desire (Neumann, 1971). That transformation in the context of pretend or imaginative play is the most obvious manifestation of freedom from unnecessary constraints of reality (Neumann, 1971; Parham et al., 2011; Rubin et al., 1983; Sawyer, 1997). One of the "paradoxes of play" (Bateson, 1972) is represented in a child's transformation, for example, of a bolster swing into a horse and himself into a rodeo rider. In making both himself and the swing into something that they are not (a horse and a rider), the therapeutic activity takes on "real" meaning for the child. This increased meaningfulness probably would not have been present if the activity consisted only of the child, as himself, trying to stay on the swing as long as possible while the therapist shook it.

Relative freedom from unnecessary constraints of reality involves more than pretend. For children with sensory integrative dysfunction, objective reality commonly presents many constraints, not the least of which may be fear of moving or fear of being touched. Gravity also presents an inordinate constraint to children whose muscle tone or posture is not adequate to resist it or who fear falling or being out of an upright position. Complex toys may inhibit a child whose motor planning skills are poor. A therapist seeks to orchestrate intervention so that constraints are minimized. In creating a safe environment free of constraints or consequences that prevent a child from succeeding in "real life," reality is temporarily suspended and both play and therapeutic gain are facilitated (Vandenberg & Kielhofner, 1982).

Similar to Phoebe's therapist, most therapists who work routinely with children are relatively comfortable with and quite skilled at participating in pretend play frames and adjusting the physical environment to minimize the negative consequences of sensory integrative dysfunction. However, other aspects of suspending reality may be more difficult. For example, playful mischief is an aspect of suspension of reality that sometimes makes adults uncomfortable. Mischief involves breaking the usual rules. Squirting an adult with a squirt gun, hitting an adult with a pillow, or jumping off a table are not allowed in most situations. Certainly, they would not be allowed in therapy if children were doing them maliciously. However, we must distinguish between meanness, maliciousness, and playful mischief. Playful mischief requires skill and is done with a sparkle in the eye (Skard & Bundy, 2008). Perhaps because children perceive them as "naughty," mischievous acts can be highly motivating. Another benefit of playful mischief is that it provides opportunities to learn that certain behaviors are okay at some times but not okay at other times. Reading the cues that allow one to match behaviors to circumstances is a worthwhile goal for many children.

Play Element 4: Framing

Framing is about giving and reading cues that tell players how to treat one another in play. Sometimes cues are verbal, "Let's play . . .," but, more often, they are nonverbal (e.g., hitting gently so as not to hurt your playmate in a play fight). When players respond skillfully to the cues of a playmate, they increase the likelihood that all players will have fun. Developing the ability to read cues and support a playmate's play likely requires a specific intervention. Wilkes-Gillan and colleagues (Cantrill, Wilkes-Gillan, Bundy, Cordier, & Wilson, 2015; Wilkes-Gillan, Bundy, Cordier, & Lincoln, 2014a, 2014b; Wilkes-Gillan, Bundy, Cordier, Lincoln, & Hancock, 2014, 2015) described innovative interventions with children with attention deficit-hyperactivity disorder (ADHD) designed to improve play by helping the children respond to playmates' cues and support their play. Wilkes-Gillan et al.

(2014a, 2014b, 2014, 2015) used three primary strategies:

1. Playing with the children in the clinic, modeling supportive play.
2. Review and analysis of videotapes of the children playing with a regular playmate, done together with the children.
3. A home-program that involved a videotape of an alien learning to play as an Earthling.

Reading cues is critical to success as a player outside of the supportive environment of the clinic, and children with sensory integrative dysfunction often seem to have difficulty reading cues. Reading play cues is not a construct associated with sensory integrative therapy, but therapists might consider building it into the play that *is* a part of all sessions.

Particularly in the early stages of therapy, Phoebe's therapist was closely attuned to Phoebe's cues. She was a vigilant observer, deciding exactly how far to push to get the best from Phoebe. However, it is unlikely that Phoebe was capable of reading subtle play cues from the therapist. Thus, the therapist made it easier by exaggerating her cues. When Phoebe took a long time to climb the ladder, the therapist began snoring. When Phoebe complained that the platform swing was moving too much, the therapist put on a very innocent face and, using a voice that suggested she just did not believe Phoebe's complaint, said, "But it was a *one-finger push.*" Likely as Phoebe moved through the therapy process, she would have required the therapist to exaggerate her cues less.

HERE'S THE POINT

- Play is the essence of childhood and of SI intervention.
- Play is intrinsically motivating, relies on the child's inner drive, and allows the child to be and feel in control.
- Play in the context of intervention involves a careful balance of freedom from rules and the constraints of reality, with some subtle (and unobtrusive) structure and framing by the therapist.
- Being playful with children, and watching them flourish through play with us, is what makes our work so enjoyable, satisfying, and effective.

Play and Fidelity to Treatment

Fully half of the process criteria that Parham and colleagues (2011) listed as defining sensory integrative therapy in their Fidelity Measure pertain to therapy as play and the therapist as a skilled playmate and promoter of play. Not surprisingly, all of Parham and colleagues' (2011) key strategies describe ways of helping the child feel internal control. For example, "providing structure and support for adaptive responses while allowing the child to be actively in control as much as possible" (p. 14) is the key issue for "collaborates in activity choice." Ayres (1972) and others (Lane, Smith Roley, & Champagne, 2013; Stackhouse, 2014) have called an adaptive response one that is just a little better, easier, or more spontaneous. The tie between motivation and challenge is clear.

Tailoring activity to present the just-right challenge also speaks to helping a child feel control. Numerous theorists (Ayres, 1972; Csikszentmihayli, 1975a, 1975b, 1990, 1993, 1996, 1997; Poulsen, Rodger, & Ziviani, 2006) have indicated that all of us become most involved when we reach to the ends of our capabilities. Perhaps reflecting the intense engagement that accompanies a just-right challenge, Dunkerley and colleagues (1997) observed what appeared to be "working" rather than "playing." They also observed that the children appeared "somewhat anxious" (p. 804), which Neiss (1988) explained by saying that a certain level of anxiety may be needed to perform at peak. Shaping the just-right challenge can be difficult. Ayres indicated that these optimum-for-growth moments that allow the child to experience mastery (Ayres, 1972) are often embedded within moments of fun and moments of failure. Over-challenges allow children to experience failure without dire consequences (also a trait of play). Ensuring success, another process criteria in Parham and colleagues' Fidelity Measure, does not mean that a child never fails to hit a target. In fact, we all would become quite bored if every attempt yielded success.

Feeling physically and emotionally safe is a very basic aspect of internal control, and Parham and colleagues (2011) listed it as an important strategy for "establishing a therapeutic alliance." In therapy, unlike in "real life," children can joyfully leap off surfaces and swing through the air, all the while feeling safe. They are firmly ensconced in a supportive net hammock, and the surfaces below them are covered in thick foam padding. But feeling safe, similar to ensuring success, does not mean that a child will never fall down (Csikszentmihayli, 1975a, 1990, 1993, 1996). The artful therapist remains near enough to be involved (and prevent serious accident), yet far enough away to promote self-direction and give the message that the child is capable. The art lies in knowing how much support and when.

Summary and Conclusions

The most effective intervention reflects a partnership between art and science. As in all good partnerships, the relationship is fluid. One may predominate for a time, but both make equal contributions in the long run. Whereas science is associated explicitly with knowledge and theory (Mosey, 1981), art seems intuitive, ethereal. Science allows us to situate a session in the proper constructs of SI theory. Art is fluid and allows for the ever-adapting activity required to meet the moment-by-moment needs of a child (Creighton, Dijkers, Bennett, & Brown, 1995; Peloquin, 1989, 1998). Peloquin (1989) indicated that art is the soul of occupational therapy practice. Art transforms therapy. "Without art . . . occupational therapy would become the application of scientific knowledge in a sterile vacuum" (Mosey, 1981, cited in Peloquin, 1989, p. 220). Artist Alex Grey (1998) wrote, "The artist's mission may not ever be reduced to words or rationally understood, but its invisible magnetizing presence will infuse an artist's work completely" (p. 10).

Peloquin (2005) concluded, as we do, that "Grains of sand and waves of sea together make seaside. Seaside would not *be* if one were gone" (p. 619). "Effective practice is artistry and science" together (p. 613).

Where Can I Find More?

Ayres, A. J. (1972). The art of therapy. In A. J. Ayres, *Sensory integration and learning disorders* (pp. 256–266). Los Angeles, CA: Western Psychological Services.
In her original book on SI, Ayres clearly articulates that therapy is both art and science. This chapter describes the art that is needed to support organization of the brain.

Skard, G., & Bundy, A. C. (2008). Test of playfulness. In L. D. Parham & L. S. Fazio (Eds.), *Play in occupational therapy for children* (2nd ed., pp. 71–94). St. Louis: Mosby.
This chapter contains more information on observing and promoting play and playfulness.

References

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Bateson, G. (1972). Toward a theory of play and fantasy. In G. Bateson (Ed.), *Steps to an ecology of the mind* (pp. 177–193). New York, NY: Bantam.

Bundy, A. C., & Lane, S. (2002). *Sensory integration: Theory and practice* (2nd ed.). Philadelphia, PA: F. A. Davis.

Caillois, R. (1979). *Man, play, and games.* New York, NY: Schocken.

Cantrill, A., Wilkes-Gillan, S., Bundy, A., Cordier, J., & Wilson, N. (2015). An eighteen-month follow-up of a pilot parent-delivered play-based intervention to improve the social play skills of children with attention deficit hyperactivity disorder and their playmates. *Australian Occupational Therapy Journal, 62*(3), 197–207. doi:10.1111/1440-1630.12203

Creighton, C., Dijkers, M., Bennett, N., & Brown, K. (1995). Reasoning and the art of therapy for spinal cord injury. *American Journal of Occupational Therapy, 49,* 311–317.

Csikszentmihayli, M. (1975a). *Beyond boredom and anxiety.* San Francisco, CA: Jossey-Bass.

Csikszentmihayli, M. (1975b). Play and intrinsic rewards. *Humanistic Psychology, 15,* 41–63.

Csikszentmihayli, M. (1979). The concept of flow. In B. Sutton-Smith (Ed.), *Play and learning* (pp. 257–274). New York, NY: Gardner.

Csikszentmihayli, M. (1990). *Flow: The psychology of optimal experience.* New York, NY: Harper-Collins.

Csikszentmihayli, M. (1993). *The evolving self: A psychology for the third millennium.* New York, NY: Harper-Collins.

Csikszentmihayli, M. (1996). *Creativity: Flow and the psychology of discovery and invention.* New York, NY: Harper-Collins.

Csikszentmihayli, M. (1997). *Finding flow: The psychology of engagement with everyday life.* London, UK: Basic Books.

Deci, E. L., & Ryan, R. M. (2000). The 'What' and 'Why' of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11,* 227–268.

Dunkerley, E., Tickle-Degnen, L., & Coster, W. (1997). Therapist-child interaction in the middle minutes of sensory integration treatment. *American Journal of Occupational Therapy, 51,* 799–805.

Grey, A. (1998). *The mission of art.* Boston, MA: Shambhala.

Lane, S., Smith Roley, S., & Champagne, T. (2013). Sensory integration and processing: Theory and application to performance. In B. Schell & G. Gillen (Eds.), *Willard & Spackman's occupational therapy* (12th ed., pp. 816–868). Philadelphia, PA: Lippincott, Williams & Wilkins.

Mosey, A. C. (1981). *Occupational therapy: Configuration of a profession.* New York, NY: Raven.

Neiss, R. (1988). Reconceptualizing arousal: Psychobiological stress in motor performance. *Psychological Bulletin, 103,* 345–366.

Neumann, E. A. (1971). *The elements of play.* New York, NY: MSS Information.

Parham, L. D., Roley, S. S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on the effectiveness of the Ayres Sensory Integration® intervention. *American Journal of Occupational Therapy, 65,* 133–142.

Peloquin, S. M. (1989). Sustaining the art of practice in occupational therapy. *American Journal of Occupational Therapy, 43,* 219–226.

Peloquin, S. M. (1998). The therapeutic relationship. In M. E. Neistadt & E. B. Crepeau (Eds.), *Willard & Spackman's occupational therapy* (9th ed., pp. 105–119). Philadelphia, PA: Lippincott, Williams & Wilkins.

Peloquin, S. M. (2005). Embracing our ethos, reclaiming our heart. *American Journal of Occupational Therapy, 59,* 611–625.

Poulsen, A. A., Rodger, S., & Ziviani, J. M. (2006). Understanding children's motivation from a self-determination theoretical perspective: Implications for practice. *Australian Occupational Therapy Journal, 53*(2), 78–86.

Rubin, K., Fein, G. G., & Vandenberg, B. (1983). Play. In P. H. Mussen (Ed.), *Handbook of child psychology: Socialization, personality and social development* (4th ed., Vol. 4, pp. 693–774). New York, NY: Wiley.

Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and extrinsic motivation: Classic definitions and new directions. *Contemporary Educational Psychology, 25,* 54–67.

Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55,* 68–78.

Sawyer, R. K. (1997). *Pretend play as improvisation: Conversation in the preschool classroom.* Mahwah, NJ: Lawrence Erlbaum Associates.

Schön, D. (1983). *The reflective practitioner: How professionals think in action.* New York, NY: Basic Books Inc.

Skard, G., & Bundy, A. C. (2008). Test of playfulness. In L. D. Parham & L. S. Fazio (Eds.), *Play in occupational therapy for children* (2nd ed., pp. 71–94). St. Louis, MO: Mosby.

Stackhouse, T. M. (2014). The adaptive response to the just-right challenge: Essential components of sensory integration intervention. *Sensory Integration Special Interest Section Quarterly, 37*(2), 1–4.

Sutton-Smith, B. (1997). *The ambiguity of play.* Cambridge, MA: Harvard University.

Tickle-Degnen, L., & Coster, W. (1995). Therapeutic interaction and the management of challenge during the beginning minutes of sensory integration treatment. *Occupational Therapy Journal of Research, 15,* 122–141.

Vandenberg, B., & Kielhofner, G. (1982). Play in evolution, culture and individual adaptation: Implications for therapy. *American Journal of Occupational Therapy, 36,* 20–28.

White, R. W. (1959). Motivation reconsidered: The concept of competence. *Psychological Review, 66,* 297–323.

Wilkes-Gillan, S., Bundy, A., Cordier, R., & Lincoln, M. (2014a). Eighteen-month follow-up of a play-based intervention to improve the social play skills of children with ADHD. *Australian Occupational Therapy Journal, 61,* 299–307. doi:10.1111/1440-1630.12124

Wilkes-Gillan, S., Bundy, A., Cordier, R., & Lincoln, M. (2014b). Evaluating a pilot parent-delivered play-based intervention for children with ADHD. *American Journal of Occupational Therapy, 68,* 700–709. doi:10.5014/ajot.2014.012450

Wilkes-Gillan, S., Bundy, A., Cordier, R., Lincoln, M., & Hancock, N. (2014). Child outcomes of a pilot parent-delivered intervention for improving the social play skills of children with ADHD and their playmates. *Developmental Neurorehabilitation*, *19,* 238–245 doi/full/10.3109/17518423.2014.948639

Wilkes-Gillan, S., Bundy, A., Cordier, R., Lincoln, M., & Hancock, N. (2015). Parents' perspectives on the appropriateness of a parent-delivered intervention for improving the social play skills of children with ADHD. *British Journal of Occupational Therapy, 78*(10), 644–652. doi:10.1177/0308022615573453

CHAPTER 13

The Science of Intervention: Creating Direct Intervention from Theory[1]

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The child's sense of fulfillment radiates as he . . . pits himself against gravity and finds that it is not quite the ruthless master it was a short time before. . . . He is no longer the impotent organism shoved about by environmental forces; he can act effectively on the world.

—A. Jean Ayres (1972, p. 262)

Intervene: To come between as an influencing force.

—Webster's New World Dictionary

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Apply sensory integrative theory to the creation of intervention activities.
- ✔ Generate intervention activities to improve performance of children with specific sensory integrative disorders.
- ✔ Integrate practical considerations for practice, including length of sessions and physical environment, into the design of treatment activities.

Purpose and Scope

In this chapter, we describe the creation of therapeutic activities that directly reflect sensory integration (SI) theory: the science of intervention. We present a variety of therapeutic activities designed to link enhanced sensation together with a just right challenge in order to ameliorate particular difficulties associated with sensory integrative dysfunction. Rarely does any therapeutic activity meet only one objective. The difficulty is to determine which, of all the possible applications an activity might have, is most appropriate for this child at this particular point in intervention and on this particular day. Because we frequently alter activities as we go, we must always have a clear idea of what we hope to achieve in order to adapt activities appropriately. To stay true to the science of sensory integrative therapy, we rely heavily on the model that depicts the theory. We presented this model in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) and reprint it here

[1]Suspended equipment is a hallmark of sensory integrative therapy. Throughout this chapter we refer to several pieces of suspended equipment. The chapter is sprinkled liberally with photographs of suspended equipment. The Appendix to this chapter also provides a list of equipment vendors.

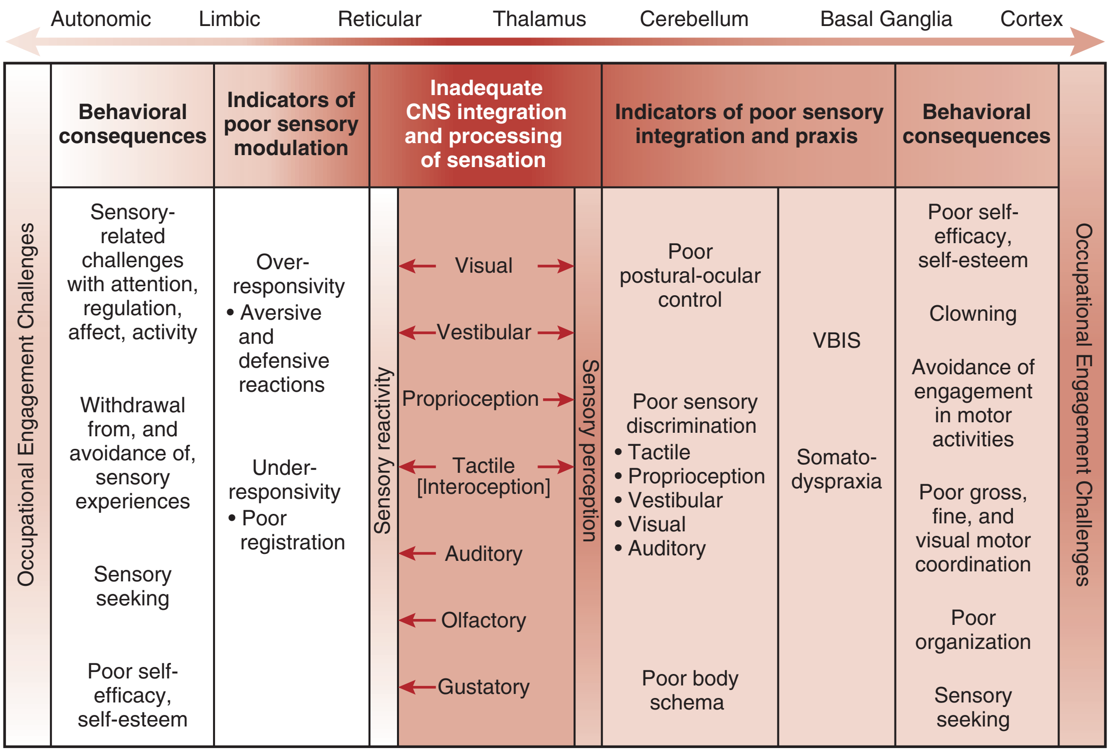


FIGURE 13-1 A schematic representation of sensory integration theory.

(see Fig. 13-1). Throughout this chapter, we will refer to this model as a continual reminder of the link between enhanced sensations and desired therapeutic outcomes.

The science of sensory integrative therapy helps us tailor the **just-right challenge** and the expected **adaptive responses** to the particular needs of a child. These are key elements of sensory integrative therapy (Ayres, 1972; Lane, Smith Roley & Champagne, 2013; Stackhouse, 2014). That is, in therapy, a child is enabled to respond adaptively to tasks and environmental demands at the highest level possible (Smith Roley, Mailloux, Miller-Kuhaneck, & Glennon, 2007) in ways determined through rigorous assessment. Activities reflecting the just-right challenge are motivating and engaging because they match the child's interests and the child can master them using focused effort (Case-Smith, 2010). In addition, problem-solving and the ability to make ongoing adjustments to a motor strategy are important components of an adaptive response.

Parham and colleagues (2007) defined 10 process elements of sensory integrative therapy. These elements can be divided roughly into two categories: those that primarily support science and those that primarily reflect art. In Chapter 12 (The Art of Therapy), we addressed the process elements associated with art. Here we address those that most closely reflect the science of intervention. Thus, the focus in this chapter is on creating and modifying therapeutic opportunities that (a) support self-regulation and sensory awareness; and (b) challenge postural ocular control, bilateral integration, conceptualizing and planning novel motor tasks, and organizing behavior. Our goal here is to contribute to readers' abilities to apply SI theory by providing ideas for meaningful activities to ameliorate specific aspects of sensory integrative dysfunction.

We first present a brief case of a child with difficulties common to many who experience sensory integrative dysfunction. We follow the case with sections on enhanced sensation and intervention for difficulties with sensory modulation and praxis. We then address intervention to promote sensory discrimination. Finally, we offer a section on practical considerations for intervention.

CASE STUDY ■ SAM

Seven-year-old Sam is struggling to participate successfully in a variety of contexts. He is hesitant to join novel social situations, often clinging to his mother's leg. But, once engaged, Sam tends to "ramp up" quickly. The pitch of his voice rises, his activity level increases, and he becomes "pushy and aggressive" toward others. Play dates and birthday parties often end, for Sam, with a "meltdown" that can last up to 20 minutes.

In school, Sam slumps, leans excessively, and, occasionally, falls out of his chair. He finds it hard to keep up with peers in activities that involve motor skills. Handwriting is a particular challenge. Sam has difficulty orienting his pencil in his hand for optimal use; he uses a tight pencil grasp and writes with too much pressure, frequently tearing his paper.

To most observers, Sam looks clumsy. He has difficulty kicking, throwing, and catching a ball and navigating safely and effectively through space, particularly with moving objects or people. He cannot ride a bicycle without training wheels and still descends stairs one foot at a time. During gym class, Sam is often seen flopping onto the ground or crashing into other children. At recess, he tends to hang back and watch the other children, or he incites them to chase him. Chasing frequently ends with Sam falling and hurting himself or pushing another child down.

Sam's mother reports that Sam was much slower than his siblings in developing independence for daily tasks, such as getting dressed, brushing his teeth, and using utensils. He is picky about the clothes he wears and foods he eats. He often complains that clothes are too scratchy and tooth brushing "hurts." The sight of some foods causes him to throw a tantrum in anticipation of the taste or texture.

Sensory Integration and Praxis Test (SIPT) scores and clinical observations revealed somatodyspraxia (SD) that stems from poor processing of vestibular, proprioceptive, and tactile sensations. Sensory Processing Measure (SPM) results suggested mild over-responsiveness to all forms of sensation that seem to contribute to, but not fully explain, his poor regulation. Based on the model presented in Figure 13-1 and the Ayres Sensory Integration© Fidelity Measure (ASIFM) that appears in Chapter 14 (Distilling Sensory Integration Theory for Use: Making Sense of the Complexity), we will co-create activities with Sam that provide opportunities for him to take in enhanced tactile, vestibular, and proprioceptive sensation in the context of activities that challenge his postural–ocular control and motor planning at appropriate levels (i.e., the just right challenge). We will monitor his ability to attain and maintain appropriate levels of arousal in the face of enhanced sensation, but even more pertinently, provide challenges to his posture and motor planning. We describe such activities in the relevant sections that follow.

Providing Opportunities for Enhanced Sensation

Sensory integrative therapy is characterized by enhanced sensation gained through *active* engagement in meaningful activities (i.e., play). Specific sensations are selected according to the intended goal (see Fig. 13-1). The essence of sensory integrative therapy is that enhanced sensation derived from active movement, when carefully matched to a child's needs and state, (a) helps with regulation of arousal to support engagement and (b) enhances body schema and postural control for improved motor planning. In a nutshell, sensory integrative therapy comprises enhanced sensation and active engagement in carefully created, playful activities. In SI theory, enhanced sensation generally refers to proprioception, vestibular, and tactile sensations. See also Chapter 4 (Structure and Function of the Sensory Systems) for in-depth information about the specific inputs received and interpreted by each system. Here we provide only a brief summary.

Proprioception is received by receptors in the muscles and, to a lesser extent, the joints. Muscle receptors are activated in response to resistance, whereas joint receptors are activated in response to joint movement. Proprioception contributes to body scheme and our knowledge of position in and movement through space. Poor processing of proprioception results in difficulty judging the timing of movement and the amount of force needed for a task. It also leads to difficulty determining the angle of joints and thus the relative position of body parts. Sam has a tight pencil grip and utilizes too much pressure when writing. His clumsiness might be a function of poorly timed movements, or inadequate knowledge of where he is in space.

The vestibular system is responsible for discrimination of sensation that helps with maintaining posture and a stable visual field. Two categories of sensory organs comprise the vestibular system: the otolith organs (linear movement and gravity receptors) and the semicircular canals (angular movement receptors). Poor processing of sensation received by the *otolith organs* results in decreased proximal extensor muscle tone, as observed with Sam who slumps at his desk. It can contribute to difficulty determining the precise spatial orientation of the head. Is it tilted or upright? Poor processing of otolithic information is also thought to contribute to gravitational insecurity and to some compensatory eye movements. In contrast, poor processing of sensation received by the *semicircular canals* is seen in difficulty eliciting the small, rapid movements needed for effective equilibrium reactions and postrotary Nystagmus (PRN) and can also result in aversive responses to movement. Poor equilibrium reactions may contribute to Sam's difficulty riding a two-wheel bicycle.

The skin is the receptor organ for tactile sensations. Poor tactile discrimination is defined as difficulty knowing the precise location and properties of touch; it can greatly impact body scheme because it interferes with our understanding of body boundaries. Poor tactile discrimination may also impact the development of oral, fine, and, to some extent, gross motor skills and motor planning. Sam, for example, has struggled with developing independence in activities of daily living (ADLs) and has difficulty catching, throwing, and kicking, all of which could be related to poor tactile (as well as proprioceptive and vestibular) discrimination. His difficulty orienting a pencil in his fingers for writing likely reflects inadequate tactile discrimination for this fine motor task. When a child with poor tactile discrimination manipulates small objects, it may look as though the child is wearing gloves. That child may appear messy or sloppy, with food left on the face or clothing crooked and disheveled. Visual hypervigilance during activity may indicate lack of specificity of tactile input; the child must rely on the visual system for activity because of the inadequate information from touch. Poor processing of tactile sensation can also manifest as tactile defensiveness, or an exaggerated response to normal tactile sensations. Sam's complaints about clothing and responses to food reflect his tactile defensiveness.

A child's response to enhanced sensation varies greatly depending on both internal and external factors. Thus, vigilant observation on the part of the therapist is essential. Creation of effective therapeutic activities depends on several factors including the particular sensory integrative difficulties the child experiences and the desired outcome (Smith Roley, 2006). Chapter 5 (Praxis and Dyspraxia) and Chapter 6 (Sensory Modulation Functions and Disorders) provide in-depth information about the nature of sensory processing problems associated with poor modulation and praxis, and Chapter 7 (Sensory Discrimination Functions and Disorders) comprises information on discrimination and perception.

Qualities Affecting the Intensity of Sensation

In addition to considering *which* sensory systems to focus on (i.e., tactile, vestibular, proprioceptive), a therapist also must consider the **intensity** of the sensation. Several *qualities* of sensation influence intensity: strength, rhythmicity, duration, frequency, and speed.

Strength is the force with which sensation is administered. Touch, for example, can be soft or firm. **Rhythmicity** is the regularity of repetition of the sensation. For example, a swing yields rhythmic input when a child propels it smoothly back and forth or arrhythmic input when a therapist jostles it as though it were being "blown in a storm." Tactile and proprioceptive input can also be rhythmic or arrhythmic. **Duration** is the length of time a sensation is present, **frequency** is how often a sensation occurs, and **speed** refers to the rate of stimulus occurrence. For example, touch can be slow as in stroking one's arm or fast as in a tickling. Similarly, movement of a body's muscles and joints can also occur at various speeds.

Together, the qualities of sensation, in conjunction with the child's current arousal level, determine the effect. Slow, rhythmic, gentle sensations tend to be perceived as less intense. When we think in terms of modulation and arousal, they have a calming effect, whereas fast, changing rhythms are likely to be perceived as more intense and to be alerting. The relationship of duration to perceived intensity and effect depends on the other characteristics. For example, deep pressure applied for long periods of time is likely to be calming, whereas light touch applied for an equal amount of time may be perceived as very intense and increase levels of arousal.

Enhanced sensation affects more than arousal and modulation; it also affects body scheme and motor functions. Tactile, vestibular, and proprioceptive sensations are associated with different motor functions ("Indicators of poor sensory integration and praxis") as shown in Figure 13-1, which is a model of dysfunction, thereby depicting difficulties associated with poor processing of sensation. However, *adequate* processing of sensation contributes to strengths in the areas listed. For example, well-functioning visual, vestibular, and proprioceptive systems contribute to good postural-ocular control.

Once again, because it bears repeating, *enhanced sensation in the context of meaningful activity is a core part of all SI therapy.* However, the reasoning behind activity choice and type of sensation will vary considerably depending on the desired outcomes and the specific needs of the individual.

A Note on Craving Sensation

Some children who have decreased sensory discrimination or who seek to alter their arousal levels seem to crave enhanced sensation (Schoen, Miller, Brett-Green, & Nielsen, 2009). They may love spinning or swinging, intentionally crash into people or things, trail their hands along the wall as they walk, or put everything in their mouth. However, craving is not necessarily a sign that enhanced sensation will be therapeutic. Not all children who crave sensation have poor sensory processing and not all children who have poor sensory processing crave the sensations they need. Vigilant observation is essential to make necessary changes as quickly as possible if a child's response to the sensation is undesirable.[2]

[2]If a child appears to "overload" after receiving intense sensation, proprioceptive and deep tactile pressure activities can help the child regain a more optimal level of arousal.

Intervention for Sensory Modulation Dysfunction

Sensory modulation deficits result in responses that are consistently disproportional to the magnitude of the sensory experience. In this section, we provide guidelines for utilizing enhanced sensation to promote modulation. We focus on the left side of the model shown in Figure 13-1, labeled "Indicators of poor sensory modulation." Because each child and each session are unique, a therapist continually must be aware of the type, qualities, and effect of the sensations inherent to an activity and the environment and then compare the expected responses with the child's actual responses. We discuss intervention for three specific categories of sensory modulation dysfunction: over-responsivity, under-responsivity, and paradoxical or fluctuating responsivity. We also briefly address intervention to alter arousal levels.

Treatment Guidelines for Sensory Over-Responsivity

In Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) and Chapter 6 (Sensory Modulation Functions and Disorders), we described two categories of sensory over-responsiveness: defensiveness and aversive responses. Defensiveness can occur in any sensory system: tactile, auditory, and so on. However, defensiveness to vestibular sensation has a specific name: gravitational insecurity, which can be distinguished from other aversive responses to movement.

Sensory Defensiveness

Defensiveness is manifested as a fight-or-flight reaction to sensations that most people do not find uncomfortable. Intervention to ameliorate defensiveness in any sensory system involves active movement that yields enhanced vestibular, proprioceptive, or tactile sensation. Sensory integrative theory postulates that enhanced input to these basic senses mediates modulation of *all* sensation. Ayres (1972) also suggested that, because certain sensations have a *central* effect, providing input to some areas of the body should be sufficient; it should not be necessary to provide input to the entire body. The mouth and face may be exceptions. Children who are particularly defensive around the face and mouth may

FIGURE 13-2 Deep pressure is often acceptable on the trunk and limbs. *Photo courtesy of Shay McAtee, printed with permission.*

need experiences with input directed to those areas (as tolerated). Whistles, kazoos, straws, or chew toys can be a good way to provide input to the sensitive areas of the mouth and face.

In general, children find deep pressure touch, proprioception, and slow, linear vestibular input easiest to tolerate. Thus, when children are particularly defensive, we begin with one of these. When enhanced tactile sensation is part of an activity, children usually tolerate input to the arms and legs more readily than the face. Deep pressure, however, is often acceptable on the trunk as well as the limbs, such as using a therapy ball as a "steam roller" over a child's back, arms, and legs (see Fig. 13-2). Enhanced sensation to promote modulation is always built into meaningful activity with the child's active participation; it is not administered passively.

As children become better able to modulate sensation, they are able to engage in activities yielding relatively intense or unpredictable sensation. For example, a child who is able to modulate sensation well should be able, in most circumstances, to experience light, unexpected touch or visual clutter without responding negatively. Any activities that generate the desired intensity of input can be used. Table 13-1 comprises several activities that provide tactile, vestibular, or proprioceptive input of varying intensities.

TABLE 13-1 Examples of Activities Providing a Range of Intensities of Enhanced Sensation

- Moving in a large container of plastic balls or ball pit
- Crawling or burrowing under textured pillows
- Painting and drawing in shaving cream, foam soap, and finger paint
- Finding objects hidden in a tactile bin filled with beans, rice, or macaroni
- Playing with a massager or vibrating toy
- Blowing kazoos or whistles
- Swinging—slowly or rapidly—on a swing suspended from two points while engaged in activity
- Swinging—slowly or rapidly—on a swing suspended from one point while engaged in activity
- Jumping up and down on a trampoline
- Bouncing on a swing suspended from a bungee cord
- Falling into a crash mat or ball pool from a stationary object or moving swing

Treatment to promote modulation should *not* be confused with approaches that target desensitization. Desensitization involves repeated stimulation until a person habituates to that stimulus. In contrast, SI therapy focuses on using combinations of vestibular, proprioceptive, and tactile sensations to *promote modulation across modalities.*

Gravitational Insecurity

Ayres (1979) described gravitational insecurity as a particularly devastating form of sensory integrative dysfunction. Symptoms include fear or anxiety from moving, particularly into backward space (e.g., tilting backwards, moving into supine) or being upside down. Everyday activities such as turning somersaults, stepping over objects, walking on bumpy ground, or getting onto and off of an escalator can elicit gravitational insecurity. Each of these activities changes the relationship between our gravity receptors and gravity input. The child with gravitational insecurity perceives this discrepancy as alarming because vestibular and proprioceptive, and likely visual, input is not being processed and integrated adequately. High arousal, which often accompanies gravitational insecurity, can severely impact participation in all daily life occupations. Chapter 6 (Sensory Modulation Functions and Disorders) contains a thorough description of gravitational insecurity.

Intervention for gravitational insecurity involves activities that provide controlled proprioceptive and linear movement (i.e., vestibular sensation) as tolerated, coupled with simple visual demands. The therapist carefully alters activities so they do not elicit fear responses and, by carefully grading activities, providing the just-right challenge and facilitating comfort with increasing head and body movement.

Control is particularly important for children who experience gravitational insecurity. Some young children cannot tolerate even slow, linear movement on equipment. For them, walking across a mattress or up and down a ramp (Fig. 13-3) may provide the just right challenge. Small linear, vertical movements (e.g., jumping, bouncing) are typically the first tolerated as they minimize head movement out of the vertical. Some children may enjoy sitting on a therapy ball together with a therapist or using equipment, such as the whale (Fig. 13-4).

When a child is able to engage in activity on a swing, sitting with the head upright is least likely to elicit fear. Further, having the child's feet on or near the floor provides tactile and proprioceptive information that promotes "grounding." As the child becomes more comfortable with moving while sitting, the therapist can incorporate activities in prone with the feet touching the ground (e.g., swinging prone over a suspended

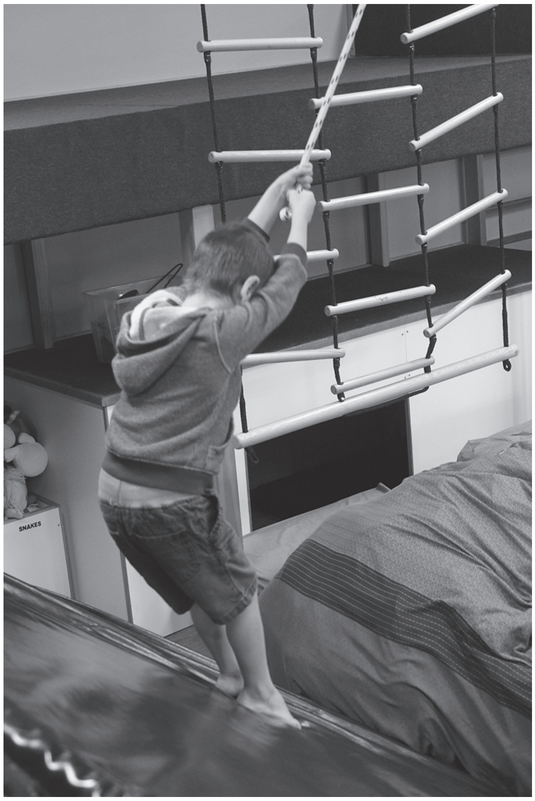


FIGURE 13-3 Walking down a ramp. *Photo courtesy of Sensory Gym.*

inner tube or frog swing, Fig. 13-5). The therapist can also position the swing close to the mat and allow the child to control the speed and direction of motion; a simple visual target provides a "fixing point" that can assist in the integration of the movement. Another tip is to have the child swing by pulling on a therapist's outstretched hands, which provides reassuring tactile input as well as proprioception and a point to fix on visually (i.e., the therapist; see Fig. 13-6). Work toward having the child propel the swing using a less stable point of control such as a hula hoop, handles, or elastic ropes.

Movement into backward space can be particularly challenging for children with gravitational insecurity because they cannot see where they are going to anticipate what will happen. Even a simple swing goes backward half the time. To help minimize some of the fear experienced by a child with gravitational insecurity, stack foam blocks or large soft pillows behind the swing at a distance that the child agrees to; these provide a clear end point to the motion.

FIGURE 13-4 Bouncing up and down on a whale. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-5 Swinging prone in the frog swing. *Photo courtesy of Shay McAtee, printed with permission.*

Table 13-2 comprises activities to address gravitational insecurity that can be graded for degree of challenge.

Children who experience gravitational insecurity need a lot of support and encouragement. They must trust the therapist completely and the therapist must earn that trust. Chapter 12 (The Art of Therapy) contains an in-depth description of an intervention session with a child who has gravitational insecurity. Some therapists have reported anecdotally that Therapeutic Listening™ or a similar program can help ameliorate gravitational insecurity (see Chapter 18, Complementary Programs for Intervention).

FIGURE 13-6 Pulling on the therapist's hands to initiate swinging provides tactile and proprioceptive input and a point to fix on visually. *Photo courtesy of Sensory Gym.*

TABLE 13-2 Sample Activities for Treating Gravitational Insecurity

- Carry a beanbag or stuffed animal across a mattress-covered surface
- Carry a slightly weighted object up a ramp
- Crawl or walk over a platform swing close to the ground that has pillows underneath to minimize movement of the swing
- Bounce up and down while seated on a therapy ball that is an appropriate size (feet on ground)
- Bounce on a whale swing (with therapist behind child) (see Fig. 13-4)
- Bounce on a mini trampoline
- Bounce up and down while seated on a frog swing suspended by a bungee cord (Fig. 13-7)
- Bounce up and down or pull on a cord (child in control of excursion) while seated on a square platform swing suspended by a bungee cord, with tire inner tube for additional support (Fig. 13-8)
- Ride prone on a scooter board across the floor
- Ride prone on a scooter board down a ramp
- Throw beanbags or balls at a large target while prone in a frog swing
- Swing back and forth while prone or seated on a platform glider suspended from two points
- Swing back and forth while seated on a bolster swing suspended from two points
- "Practice" falling from sitting with feet flat on the floor into a crash mat or pile of pillows
- Swing side-to-side while prone on a bolster swing
- Laying prone, with body wrapped around a bolster that the therapist shakes gently; progress to falling off on soft crash mats or pillows
- Bounce prone in frog swing with gradually larger excursions of movement
- Ride a zip line or trapeze, landing in large soft pillows or a crash mat

Aversive Responses to Movement

Aversive responses are manifested as autonomic nervous system reactions (i.e., nausea, vertigo, sweating, pallor) to movement that most people do not find uncomfortable, such as riding short distances in a car. Avoidance, especially of angular movement, or an increase in restlessness after a car ride may also suggest an aversive response. Aversive responses are hypothesized to be related to poor central processing of sensation received by the semicircular canals (Fisher & Bundy, 1989; May-Benson & Koomar, 2007). Chapter 6 (Sensory Modulation Functions and Disorders) contains more information on aversive responses to movement.

A general goal of intervention is to help children tolerate common movement experiences (e.g., bending over to tie shoes, riding in a car or on a swing) without feeling sick or dizzy. The goal is *not* for children to tolerate spinning or another fast rotary movement. Although activities that provide linear movement coupled with active resistance (i.e., proprioception) *may* help to minimize negative responses, aversive responses can be severe enough to impede progress in sensory integrative therapy. Therefore, aversive responses may be most effectively addressed through vestibular rehabilitation (e.g., Boyer et al., 2008; Cohen, 2000; Herdman, 1994).

Vestibular rehabilitation is a prescribed and carefully monitored program of desensitization; in-depth discussion is beyond the scope of this text. Kawar and colleagues (2005) also developed a therapy program to address vestibular concerns, titled the Astronaut Training Program. Chapter 18 (Complementary Programs for Intervention) contains some information about the Astronaut Training Program.

FIGURE 13-7 Bouncing while seated on a frog swing. *Photo courtesy of Sensory Gym.*

Treatment Guidelines for Sensory Under-Responsivity

Individuals who are under-responsive respond slowly to sensory stimuli and require a greater intensity or duration of sensation to elicit a response (Hanft, Miller, & Lane, 2000; Reynolds & Lane, 2008). Children who are under-responsive may have fewer, muted, or delayed responses to daily sensory events (Lane, Miller, & Hanft, 2000; Schoen, Miller, & Sullivan, 2014). Sensory under-responsivity can be difficult to distinguish from poor sensory discrimination. Because intervention for these two concerns overlaps, it is not always necessary to be able to distinguish between the two. Both can lead to challenges with fine and gross motor activities.

In intervention we provide frequent opportunities for enhanced sensation in order to reach the child's sensory threshold and encourage optimum alertness. This can and should target any or all of the sensory systems. Enhanced input must also be part of everyday activities including opportunities for dynamic movement, foods

FIGURE 13-8 The square platform swing with an inner tube atop for stability. *Photo courtesy of Shay McAtee, printed with permission.*

with strong tastes and smells, messy play, music with fast and changing rhythms, and brightly lit and multi-sensory environments such as active playgrounds, public swimming pools, and music and movement classes. Grading the activities listed in Table 13-1 for increased intensity can be helpful when working with children who are under-responsive.

Paradoxical and Fluctuating Responses

Some individuals who *appear* under-responsive to sensory events may actually be *overly* responsive but protecting themselves by shutting out input, such as when a fuse blows from having too many appliances plugged in. During the course of intervention, we have seen some such children shift their responses from apparently under-responsive to overtly over-responsive. Although this shift can be confusing, we have found, clinically, that it actually may be a sign of *improvement.* Although still out of proportion to the sensation experienced, the child's responses now genuinely reflect the state of the central nervous system (CNS)—that is, a child who is overly sensitive is now over-responsive, rather than failing to respond. However, therapists must proceed with caution, matching their approach to meet the changing needs of a child and realizing that the child's responses may fluctuate between over- and under-responsiveness for a period of time. The responsivity levels of children with fragile X syndrome (Miller et al., 1999), and some children with autism, also fluctuate, both within and between sensory systems, making it a challenge to create a therapeutic milieu that promotes engagement in intervention activities.

In the previous section, entitled Qualities Affecting the Intensity of Sensation, we described characteristics of sensation differentially associated with calming or alerting. When we provide enhanced sensation in the context of an activity, we expect a relatively immediate effect. Sensation that is calming should help to lower arousal and sensation that is alerting should raise arousal levels. However, SI theory suggests that through time, because of intervention, the CNS will become better able to modulate incoming sensation, less often over- or under-responding. This in turn should lead to a more adaptable and functional arousal level, with less severe fluctuations.

Modulating Arousal

In general, when children are over-responsive to sensation, they tend toward high arousal, which, in turn, makes it difficult to attend to, and engage in, activity. Sam is a child who "ramps up" easily (i.e., enters a state of hyperarousal). Similarly, under-arousal seems to accompany under-responsivity to sensation. Children whose responsivity to sensation fluctuates may also fluctuate between under- and over-arousal. One way to alter arousal levels is through opportunities for enhanced sensation for a child in the context of meaningful activity. The particular characteristics of enhanced sensation will differ depending on whether the goal is to increase or decrease arousal.

In addition to providing direct intervention to change processing in the CNS and help children attain optimal arousal, monitoring and altering the environment is also important. A low input environment with low or natural lights, muted colors, minimal clutter, and soft background sounds or silence may promote focus and feelings of calm. In Chapter 12 (The Art of Therapy), we address a therapist's therapeutic use of self that also contributes to a calming environment.

Richter and Oetter (1990) described the Matrix Model, a model of task and environment interaction. They offered guidelines for creating two types of environments that may be particularly useful when children experience over-arousal: womb space and mother space. **Womb spaces** are small, protected, and separate from the world at large, invoking feelings of security and safety. A child in a womb space receives physical contact from another person or deep pressure from a large pillow or blanket and experiences very few demands. Children with high levels of arousal may need help from an adult to move into womb space to encourage regulation. Table 13-3 presents ideas for creating womb space environments. **Mother space** provides a slightly more demanding, but nonetheless safe and nurturing

TABLE 13-3 Womb Space Environments

- Large beanbag chair
- Pop-up tent
- Large cardboard box
- Fort made out of blankets and clothes pins
- Piles of pillows
- Spandex hammock
- Spandex cuddle swing

environment. In mother space, a child is free to take simple "risks" while remaining in close proximity to an adult (typically 8 to 10 inches away). The adult often sits at the child's level and gives intermittent physical or eye contact along with short, rhythmic verbal communications.

HERE'S THE POINT

- Providing enhanced sensation as the just right challenge is the key to designing interventions for sensory over- and under-responsivity.
- Providing direct intervention *and* making changes to the environment can help modulate a child's level of arousal and may increase his or her level of attention and engagement.

Intervention for Practic Disorders

Ayres (1972, 1979, 1985) and others (May-Benson, 2014; Miller, Anzalone, Lane, Cermak, & Olsten, 2007; Smith Roley et al., 2015) proposed that difficulty with motor planning is the *primary* problem in sensory-integrative-based dyspraxia. That is, children with dyspraxia appear awkward because of poor planning rather than because of a primary problem with motor execution. They further believed that planning effective, efficient actions relies on an internal body scheme and information about body position in space, derived from the tactile, vestibular, and proprioceptive systems. The underlying processing difficulty has implications for the types of enhanced sensation we build into therapeutic activities. See the right side of the model shown in Figure 13-1 labeled "Indicators of poor sensory integration and praxis."

In sensory integrative theory, we speak of two major kinds of dyspraxia: **vestibular bilateral integration and sequencing deficits** (VBIS) and SD. VBIS is thought to be caused by inadequate processing of vestibular and proprioceptive sensations, manifesting as poor postural-ocular control, bilateral integration, and sequencing of anticipatory movements. SD is based in poor processing of tactile sensation, often in combination with poor vestibular-proprioceptive discrimination. In general, because they have fewer processing problems, we believe that children with VBIS have fewer difficulties than children with SD.

In this section, we focus on interventions to increase motor planning. Most projected action sequences, or anticipatory movements, involve both sides of the body and most children with dyspraxia have difficulty with coordinated bilateral actions. Thus, we include a segment on bilateral integration. Further, some children with dyspraxia, especially SD, have difficulty generating an idea of what to do and generalizing skills. Therefore, we also include segments on ideation and generalization. Finally, because some children have difficulties with both modulation and praxis, we include a segment on balancing intervention for multiple processing problems.

Promoting Planning

Motor planning is particularly important for new motor tasks. Not surprisingly, the ability to plan actions follows a developmental sequence. Very young, or very unskilled, children lack sophisticated planning ability. They perform motor skills using feedback (vestibular, proprioceptive, tactile, visual) gained from the action, rather than feedforward to plan for the action. For example, they may catch a ball by trapping it against the chest, using the feedback from feeling or seeing the ball at their chest rather than appropriately setting up (feedforward) to catch the ball in their hands. Young, or very unskilled, children have difficulty anticipating the position where their hands must be in order to catch the ball as it moves toward them. In the course of development, they learn to plan and execute progressively more difficult motor actions. Older, or more skilled children easily anticipate where the hands must be to catch the ball and move the hands to that place—*before* the ball hits the body. With increasing skill, catching a ball has become a feedforward-dependent task. For a relatively skilled child, the *plan* to catch the ball generates a special kind of feedback that is fed forward to an existing central model of correctness for comparison. That comparison tells the child how accurate the movement will be *before* it occurs (Fig. 13-9). Although a child may *know* whether a feedforward-dependent action will succeed before it happens, the child cannot alter the movement once the plan has been initiated. In contrast, feedback-dependent movements, such as trapping a ball against the chest, *can* be changed (or initiated) in response to feedback

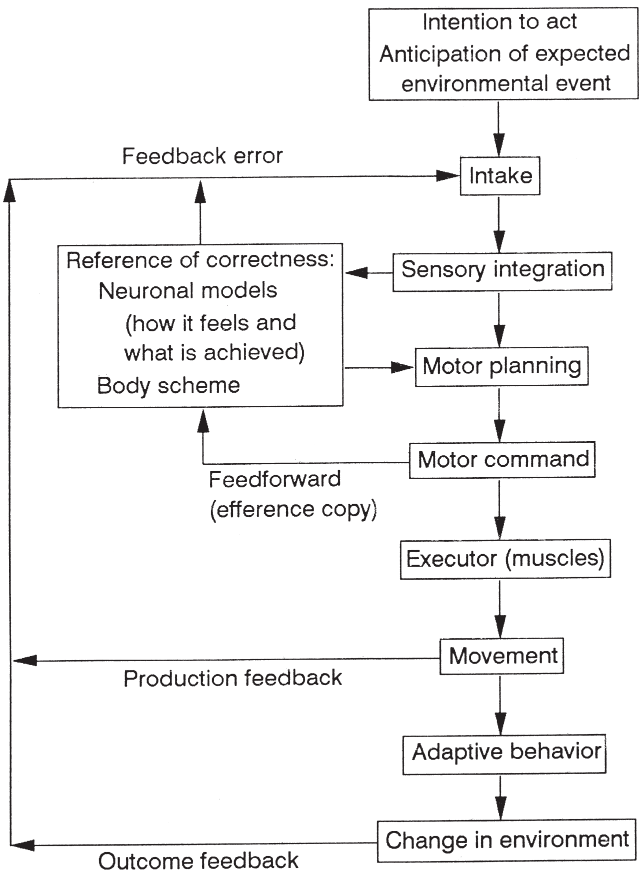


FIGURE 13-9 Schematic representation of motor planning from a sensory integrative perspective.

that comes from the action (i.e., the ball striking the body) (Seidler, Noll, & Thiers, 2004).

Feedforward-dependent tasks are often called **projected action sequences** because they involve a sequence of actions to enable projecting arms, legs, or an entire body to a precise location at an exact time in order to complete an action. Feedforward-dependent tasks have both spatial and temporal requirements (i.e., *where* do I need to move and *when* do I need to get there?), whereas the demands of feedback-dependent tasks are primarily spatial (i.e., *where* do I need to move?). Clearly, feedforward-dependent tasks are more difficult developmentally than feedback-dependent tasks.

We believe that children with VBIS have difficulty with feedforward-dependent actions, whereas children with SD tend to have difficulty with both feedforward- and feedback-dependent actions. The combined effect of (a) movements that are inefficient and ineffective, thus yielding poor quality sensory feedback, and (b) a poor ability to process feedback may mean that children with dyspraxia have difficulty establishing a central model of correctness. Thus, they may be unaware of how accurate their movements will be—until they see or hear the effect that their actions had on the environment (i.e., external feedback). In the following section, we address intervention to promote the spectrum from simple feedback-dependent to complex feedforward-dependent tasks.

Feedback-Dependent to Feedforward-Dependent Actions

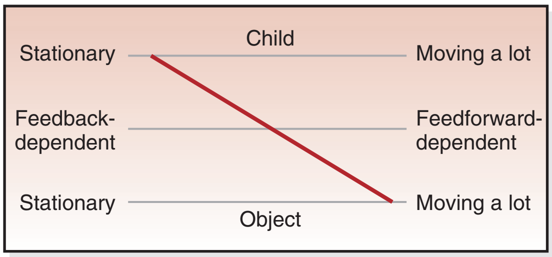
Intervention aims to promote the most complex adaptive responses possible. Thinking very simplistically, we can estimate the degree to which an activity is feedback- or feedforward-dependent by examining the movement of the child *and* the object(s) on which the child is acting (e.g., a target). Tasks where the child and target are both static are the easiest, and often a starting point in intervention for children with SD; tasks in which

HERE'S THE EVIDENCE

The ability to precisely grip and regulate grip forces is an important skill for many ADLs including writing, dressing, and eating. Initial grasp is thought to be guided primarily by feedforward control mechanisms, whereas the ability to sustain actions and maintain a constant level of motor output (grasp) is thought to rely more heavily on sensory feedback mechanisms. In their 2015 study published in the *Journal of Neurophysiology,* Wang and colleagues set out to objectively measure and differentiate motor control strategies used by children with autism spectrum disorder (ASD) during precision gripping. During testing, children with and without autism pressed against two opposing load cells while viewing visual feedback on a computer screen during multiple tests of precision grip. Results of the study indicated that children in the control group were able to adapt their initial strategy based on the task demands (target force); children with ASD tended to use only one strategy and their initial force output was less accurate overall than the control group. Further, when sustaining a constant force level, children with ASD showed increased output variability; the authors suggested that this was because of their inability to translate visual feedback information into precise motor commands. Children with ASD also had more difficulty rapidly terminating force output. Overall, these findings suggest that both feedforward and feedback motor control mechanisms are impaired in children with ASD, and they may contribute to the sensory-based motor disorders seen in this population. Although this study is specific to children with ASD, feedforward and feedback control mechanisms are thought to be compromised in children with other conditions such as dyspraxia and developmental coordination disorder. It is important that clinicians working with these populations assess both feedforward and feedback mechanisms during the initial evaluation, and provide therapeutic challenges at the just right level to elicit adaptive responses from the child throughout treatment sessions.

Wang, Z., Magnon, G. C., White, S. P., Greene, R. K., Vaillancourt, D. E., & Mosconi, M. W. (2015). Individuals with autism spectrum disorder show abnormalities during initial and subsequent phases of precision gripping. *Journal of Neurophysiology, 113,* 1989–2001.

both the child and the target are moving are the most challenging. Figure 13-10 shows a schematic representation of the relationship between the movement of a child and target to the degree of feedback- or feedforward-dependent control required. Simple modifications make activities relatively more or less challenging because they change the precision of the action required to be successful. We can create an endless array of activities to encourage planning and which produce the most difficult adaptive responses that a child can achieve (i.e., just-right challenge) by varying the size, speed, and distance of a target or the speed and range of the child's movements. Figure 13-11 shows activities involving varying degrees of spatial-temporal demands relative to the child and object.



Note: the point at which the line depicting the relative movement of child and object crosses the line marked feedback-dependent, feedforward-dependent indicates the degree of control required.

FIGURE 13-10 A conceptual representation of feedback or feedforward control, depending on relative movement of the child and object. *Adapted from Keogh & Sugden, 1985.*

When a child is on a piece of moving equipment, such as a swing or scooter board, the spatiotemporal demand of the activity is in proportion to the amount, speed, and rhythmicity of the movement of the equipment. Activities that involve slow rhythmic movement of equipment have a moderate spatiotemporal demand, especially if the target on which the child is acting is stable. (See upper right quadrant of Fig. 13-11.) A favorite activity is pretending to be a mailman or Santa's helper and delivering packages to different houses. The size of the target also contributes to spatiotemporal demand. "Houses" made from large pillows are easy targets, whereas a small box depicting a "chimney" requires more precise timing of release of the package, a greater spatiotemporal demand. Increasing the speed, continually changing the direction, or decreasing the rhythmicity of the swing's movement also increases the challenge.

Target \ Child	Stable	Moving	
Stable	☐ Jump into a hula hoop, pool, or ball pit ☐ Throw beanbag into a large stationary target ☐ Bat at a suspended ball that is still ☐ Shoot a basketball into the net while standing in front of it ☐ Stand in front of a stable ball and kick it	☐ Push or kick a large stationary ball away while moving on a scooter board or swinging in a net swing ☐ Grab beanbags or stuffed animals from the mat while swinging ☐ Propel scooter board around obstacles or through a block tunnel ☐ Bounce on a hippity hop™ through a series of small hula hoops ☐ Swing on a trapeze and land in a tire inner tube filled with pillows	Spatial demand Feedback-dependent
Moving	☐ Stand in place and kick a rolled ball ☐ Stand in place and catch a thrown ball ☐ Bat at a pitched ball while standing in a stationary position ☐ Stand and hit a suspended ball that is swinging back and forth (or tether ball) ☐ Shoot at a moving target with a squirt gun while standing in place (the larger the target, the easier) ☐ Throw beanbags at a moving target ☐ Jump up and down on a trampoline	☐ "Slap me five, high and low" while jumping on a trampoline ☐ Throw beanbags at a moving target while swinging prone in a net swing ☐ Shoot at a moving target with a squirt gun while running or swinging ☐ Bat at a swinging target while holding onto a T swing ☐ Play dodge ball, monkey in the middle, or flag football ☐ Catch a ball thrown while swinging on a swing (prone or sitting)	Spatiotemporal demand Feedforward-dependent

FIGURE 13-11 Activities illustrating relative movement of the child and object. *Adapted from Keogh & Sugden, 1985.*

Activities where both the child and the target are moving represent the greatest spatiotemporal demand. (See the lower right quadrant of Fig. 13-11.) "Bumper cars" is a highly motivating activity in that category. Two large tractor inner tubes are suspended vertically from the ceiling, about 6 feet (2 meters) apart. The child and the therapist (or two children) each straddle a tube, pulling them apart as far as possible and then swinging and crashing into one another. The object is to bump the opponent out of the tube. If a bump is to be hard enough to knock an adult out of a tube, a child's movements must be timed, sequenced, and directed precisely. Suspending the tubes high enough that the children's feet do not touch the ground and using ropes suspended between the tires to propel the tubes makes bumper cars more challenging by increasing postural and bilateral demands (Fig. 13-12).

A challenging and fun adaptation of bumper cars involves having a child running between the tubes. Two adults can easily grade the movement of the tubes. Slow, rhythmical swinging decreases the spatiotemporal demand for the child running between the tubes, whereas moving the tubes in unpredictable ways increases the challenge.

Another activity with significant spatiotemporal demand involves two children orbiting around one another in a dual swing. The two must begin moving at the same time and at the same speed. They run for a few steps and then, on cue, simultaneously lift their feet and orbit (Fig. 13-13).

A Note on Sequencing Actions

We have used the term *sequencing* to refer to ordering of a series of actions needed for acting effectively on an object (e.g., sequencing movements to get the hands to the correct place to catch a tossed ball or sequencing extension and flexion of the knees to pump a swing). However, therapists commonly use the term *sequencing* in reference to activities such as obstacle courses. In fact, obstacle courses represent sequences of sequences. The difficulty of an obstacle course is determined by the relative feedforward demand of each activity within and the speed with which a child must transition between activities. A moderately difficult obstacle course might include:

- Swinging by a trapeze from a raised surface
- Letting go of the trapeze to swing through a moving suspended inner tube onto a mat

FIGURE 13-12 "Bumper cars." *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-13 The dual swing. *Photo courtesy of Sensory Gym.*

- Leaning down to pick up beanbags
- Turning around and throwing the beanbags through the swinging tube
- Running back to the raised surface through a maze of plastic cones
- Catching the trapeze
- Beginning again

Obstacle courses can be fun and can be used to encourage the generation of ideas and spatial planning if the child participates in the design and set-up. However, they inherently decrease the opportunity a child has for repeating and mastering a single activity.

Promoting Bilateral Integration

Development of the ability to use both sides of the body together in a skillful manner (i.e., **bilateral integration;** Williams, 1983) begins very early in life; most skills are in place before a child reaches 7 years of age (Gerber, Wilks, & Erdie-Lalena, 2010; Magalhaes, Koomar, & Cermak, 1989). The body midline demarcates the two body sides and crossing the midline is an important aspect of bilateral coordination. Movements of the mouth, as a midline structure, also reflect bilateral integration.

We create meaningful activities to promote bilateral integration at the highest level of challenge a child can meet, always trying to stretch the child's skills just a little. Many skills that require bilateral coordination also involve projected action sequences (e.g., catching a ball with two hands). Placement of objects, positioning of the child relative to a target, and the amount that equipment moves all influence bilateral demands. Table 13-4 comprises four categories of bilateral

TABLE 13-4 Examples of Actions and Activities to Promote Bilateral Integration by Level of Difficulty

Bilateral Symmetrical: (Hold On and Move Actively Forward and Backward)
• *Stable object close to the body:* A child, prone or seated on a bolster swing or platform swing and holding onto the ropes with both hands, propels the swing forward and backward by actively flexing and extending the arms (Fig. 13-14). The therapist can facilitate rhythmic movement with verbal cues such as "pull-push" or "heave-ho." This action can easily be built into an activity such as having the child crash into a stack of cardboard boxes or blocks, knocking them over. Placing the boxes farther from the swing increases the challenge. A story can make the activity more meaningful. • *Stable object a short distance from the body:* A child, prone or seated on a net swing (hammock), scooter board, or platform swing, grabs the therapist's hands or a trapeze or hula hoop held by the therapist standing in front. The child grabs it (Fig. 13-15), pulls up by flexing the arms, and then releases his or her grip to swing backward. This action can be built into an activity, such as having the child demonstrate his or her strength by holding to a particular count. Another variation involves the child pulling up to refuel and hanging on while the therapist "fills the tank." Increasing the time that the child holds also increases the demand for postural stability. Having the child sit inside a tire placed on a platform swing decreases the postural demand. • *Unstable object a short distance from body:* The child is prone or seated on a net swing (hammock), scooter board, or platform swing. The child grabs two ropes suspended from the wall or ceiling approximately 6 feet (2 meters) away and propels the swing by pulling rhythmically on the ropes. This bilateral challenge can be built into "bumper tires," an activity described previously (see Fig. 13-12). Sitting on a suspended tire tube presents a greater postural demand than sitting on a hard surface (platform) or a surface that hugs the body (hammock).
Bilateral Reciprocal: (Hold On and Move Actively Side-to-Side)
• *Stable object close to the body:* A child seated sideways on a glider or bolster swing, holding onto the ropes, propels the swing side-to-side by alternately flexing and extending the arms. This action can be built into an activity where the child swings into "bop bags" (weighted rocking toys that bounce back up when hit by a swing) placed on either side of the swing. Bop bags can be placed at different distances from the two sides of the swing to alter the bilateral challenge. Standing on the swing increases the postural challenge. A story can add meaning to the game. • *Stable object a short distance from the body:* A child, prone in a net swing (hammock), uses a hand-over-hand motion to climb to the top of a rope held by the therapist. This action is easily built into an activity called "steal my magic rope." When at the top of the rope, the child "steals" it from the therapist who then grabs the loose end of the rope and "steals" it back.
Main Actor/Stabilizer (Hold On to Equipment with One Arm; Act with Other)
• A child seated on a t-swing, flexion disc (Fig. 13-16), in a hammock or other equipment, stabilizes with one arm and uses the other in activity. For example, the child could use a squirt gun to shoot at a target. Depending on the location of the target, substantial midline crossing and trunk rotation may be required. For a greater postural challenge, scatter beanbags underneath the swing for the child to pick up and throw at one or more targets. If the targets are moving, the spatiotemporal demand increases.
Alternate Opposing Actions of Arms and Legs (e.g., Flex Arms and Extend Legs)
• Swinging on a trapeze or zip line (also known as a flying fox) can easily be made into an activity that requires alternate opposing actions of arms and legs, such as swinging from a trapeze to jump through an inner tube suspended from the ceiling (Fig. 13-17) or kicking a suspended ball. These challenging bilateral tasks also require dynamic postural support and the ability to plan and execute projected action sequences.

integration that represent a developmental progression: bilateral symmetrical, bilateral reciprocal, main actor or stabilizer, and alternate opposing actions of arms and legs. To genuinely reflect the principles of sensory integrative therapy, the therapist and child must collaborate to design meaningful and appropriately challenging activities in the context of intervention.

Promoting Ideation

Children develop ideation through active exploration and interaction with objects and the environment. May-Benson (2001) proposed that children develop ideation in four areas:

- Objects: what an object can do and what can be done with it

FIGURE 13-14 Child holds a trapeze and actively flexes both arms to initiate swinging. *Photo courtesy of Sensory Gym.*

FIGURE 13-15 Child grabs the therapist's hand, pulls up by flexing the arms, and then releases his or her grip to swing backward. *Photo courtesy of Sensory Gym.*

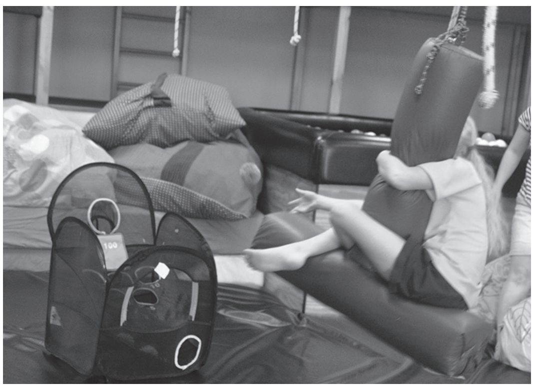


FIGURE 13-16 Child seated on t-swing stabilizes with one arm and uses the other in activity. *Photo courtesy of Sensory Gym.*

- Actions: what actions the child can do
- Appropriate Action-Object Interactions: which actions are appropriate for which objects
- Serial Actions: sequencing steps to accomplish the goal

Some children with SD and many children with autism have difficulty with conceptualizing a goal and developing a plan of how to accomplish it (i.e., ideation; May-Benson, 2014). Because of difficulty knowing what they can do with objects, children who have poor ideation seem not to recognize the *possibilities* contained within objects or situations. Consequently, they often have difficulty with self-directed or self-initiated actions (Ayres, 1985). They may wander aimlessly or gather objects but not use them. Often, they use all objects in the same very simple ways (e.g., throwing) or exhibit inappropriate actions with objects, such as trying to stand on a ball (May-Benson, 2014). They may require toys that closely resemble real objects (e.g., a toy telephone) rather than pretending that an object is something it is not (e.g., a box is a telephone). Because of the paucity of ideas, their play themes may be limited or "scripted" in unvarying ways from stories or shows. They frequently have difficulty playing, particularly by themselves, but playing with others can be problematic if they cannot understand play ideas or are overly compliant.

In therapy, we are always trying to set up an environment or activities likely to invite interaction. When working with a child for whom ideation is a problem, select familiar objects and set up specific activities. Start with activities that clearly invite a particular action but that allow the child to generate the "idea" of what to do. For example, place a familiar toy at the top of a ramp or ladder to encourage climbing (Fig. 13-18) or hide stuffed animals in a ball pit to give the child the idea to "dive in."

Some children pause before initiating a movement as though they are actively connecting the idea of what they want to do with the plan of how to do it. Allow time to process, providing only minimal instruction or feedback. Some children need physical cueing and guidance to initiate. Using a cognitive approach can help children to see possibilities in objects. For some children, peer or video modeling can be useful. Leading

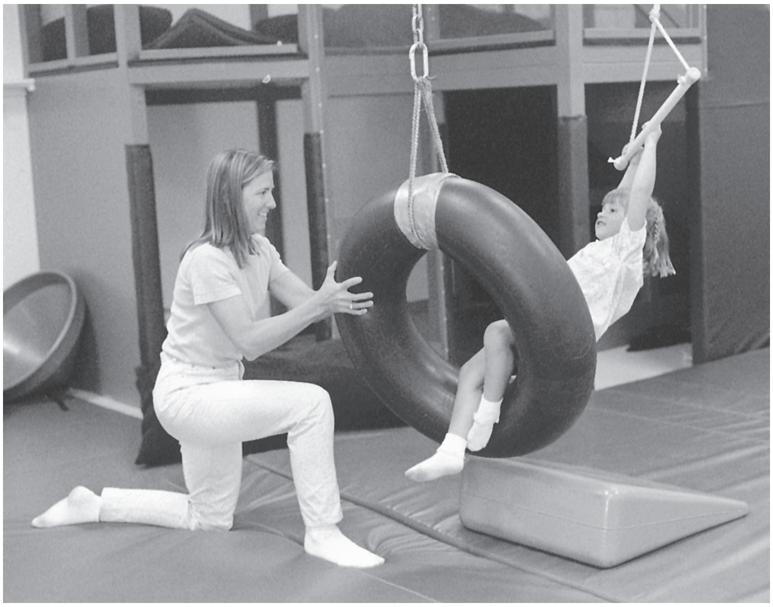


FIGURE 13-17 Swinging by a trapeze to jump through an inner tube. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-18 Place a familiar toy at the top of a ladder to encourage climbing. *Photo courtesy of Sensory Gym.*

questions, such as "What could you do with . . . ?" can be helpful for inviting a child to think of ideas. Children may be able to identify what they *have done* before they can describe what they *plan to do*.

Verbalizing a plan can assist some, but not all, children to organize their actions and carry out the plan. P.J., a 7-year-old, created a complicated obstacle course involving four pieces of suspended equipment. He even verbalized a sequence of movements to move through the course. But, when asked to demonstrate the plan, he walked to each piece of equipment and simply pushed it before moving on to the next. Children such as P.J., at least initially, may benefit more from modeling, photos of another child doing the task, or physical cues than from verbalizing a plan.

Coupling a simple motor plan with an imaginative play theme can promote ideation if the child contributes ideas about what should happen or how it can happen. Nonetheless, the level of sophistication must be targeted carefully. As Ayres (1985) indicated, "If the child leaves a task with a feeling of failure, he or she will probably not want to return to it" (pp. 67–68). Riding a "train" or a "horse" (e.g., a glider) and getting off frequently to retrieve or deliver "packages" (e.g., large, heavy beanbags or containers) is an activity that children can readily embellish (e.g., Where are they going? Who lives in the house? What's in the package?). Imaginative play often helps to capture a young child's motivation for engagement. However, children who have great difficulty with ideation and imaginative play may need concrete props such as a real ladder and rubber tubing to "pretend" to be a firefighter. Review the case study about a playful therapeutic interaction, building ideas from a child's actions.

As children gain the ability to formulate ideas for using objects, they may act more spontaneously in carefully arranged, familiar environments or do what is familiar to them in novel environments. Through time they may act spontaneously with novel objects in less familiar environments. However, some children with significant deficits in ideation may never achieve high levels of spontaneity and will need a great deal of help to generalize specific skills to home and school.

CASE STUDY ■ ALEX

When 6-year-old Alex entered the therapy session, he seemed unable to conceptualize what he might do with the equipment and instead began to run around the room. The therapist pretended that his running was purposeful. Because Alex was very interested in Winnie-the-Pooh and Pooh's friends, the therapist began talking similar to Tigger (i.e., "I love to bounce. Oh boy, a running, bouncing, jumping game!") as she modeled jumping. The therapist continued to play the part of Tigger and began pretending that Alex was Pooh. "Oh, Pooh, this is so much fun! You are such a good runner! What else can you do?" When Alex accidentally bumped into one of the bolsters, she said in an exaggerated way, "Oh, Pooh, you are so good at bumping into things!" When Alex burrowed under a large pillow, the therapist asked, "Are you Rabbit now? You are burrowing just like Rabbit."

Initiating, Carrying Out, and Generalizing New Motor Tasks

Children with dyspraxia have difficulty initiating and learning *new* motor skills; thus, intervention encourages participation in new tasks rather than simply practicing tasks that a child has mastered. Verbal mnemonics such as "ready . . . set . . . go" or "1, 2, 3, go" help some children initiate actions. Some cue themselves spontaneously but others benefit from prompting.

For some children, altering the way a familiar piece of equipment is used produces novelty: riding a swing in different positions (e.g., prone, sitting sideways) or suspending a swing from one point instead of two. The therapist can set up the environment to provide varied means to accomplish the same task. For example, a child could access the top of a platform by climbing stairs, over pillows, or up a ramp. Tasks that involve projected action sequences such as catching or kicking remain novel for a long time; a ball rarely arrives at precisely the same location, even twice in a row; thus, throwing and kicking tasks continually require new motor responses.

Actions do not always go as planned for children with dyspraxia. Understandably, these children can be easily frustrated. A gentle or humorous approach can be effective; for example, "That was the silliest jump I have ever seen! You landed on your *back* instead of your *feet.* Are those *feet* going to help you next time?" Songs or chants can assist in maintaining timing or rhythmicity of actions and may have the added benefit of lowering arousal level. Labeling children's movements as they occur (e.g., "push-pull," "jump-jump-jump") may help with both timing and rhythmicity and with cortical assimilation of body actions.[3]

To support **generalization** of a newly learned action, create new activities that require similar actions. For example, a child may jump off a pile of mats onto pillows during one session and into an inner tube later in the session or in another session. During subsequent sessions, the child may jump off the rungs of a jungle gym into an inner tube or off a slowly moving swing into pillows. As a child succeeds with a new task, point out similarities between the requirements of the current activity and those of activities

[3]A word of caution to readers. Using language does not always support praxis and, in fact, can interfere with it. Language is also praxic, and for children with challenges, it may hurt more than help. Ayres used very little language in her sessions. If you choose to use words, watch the child's response; determine if it helped, and figure out how much language is too much. Sometimes it is better to scaffold movement through action; for instance, simply pointing to where a foot should be placed or guiding a hand to reach for a ladder rung can be more effective than a verbal command.

already mastered. Generalizing actions in the clinic, however, may not be enough to allow children to generalize skills to other environments (e.g., the park or the playground) without explicit assistance. Importantly, children have not mastered an activity until they can perform it automatically and without conscious effort. Thus, practice is important.

Table 13-5 contains questions therapists might ask themselves when developing an intervention plan to promote motor planning in particular children.

HERE'S THE POINT

- Planning effective and efficient actions requires adequate processing of tactile, vestibular, and proprioceptive sensations which provide information about body position in space.
- In designing treatment activities for children with dyspraxia, the therapist should consider the feedforward and feedback demands of the task, as well as the placement and stability of the child, objects, target, therapist, and other equipment.
- For children with deficits in ideation and motor planning, the therapeutic environment should be set up to invite interaction and promote novel movement experiences.

Intervention for Increased Sensory Discrimination

Sensory discrimination is the ability to interpret the spatial and temporal qualities of sensation. In sensory integrative theory, poor sensory discrimination refers particularly to difficulties perceiving tactile, proprioceptive, or vestibular sensation, although some children with sensory integrative dysfunction also have difficulties with visual and auditory discrimination. Unlike poor sensory modulation, in which symptoms fluctuate from day to day or even hour to hour, without intervention, deficits of sensory discrimination remain relatively stable. Although difficulties with sensory discrimination *may* occur independently, in children with sensory integrative dysfunction, they are identified most commonly in conjunction with dyspraxia. In this section, we describe intervention for decreased vestibular, proprioceptive, and tactile discrimination.

TABLE 13-5 Supports for Developing Planning Abilities

- How does the child best generate ideas?
  - Specific set-up of activities
  - Imitation of peers
  - Specific suggestions
  - Picture cards
  - Leading questions
  - Independently
- How does the child best learn new activities?
  - Visually, by demonstration
  - With verbal cues
  - Through kinesthetic modeling
  - Through therapist scaffolding of movement
  - Independently by . . .
- What supports does the child need to implement a workable plan?
  - Therapist-directed plan
  - Therapist-directed steps
  - Therapist-generated supports such as lists, maps, or picture cards
  - Child-generated supports such as lists or number coding
  - Verbal guidance
- What helps the child prepare for action?
  - Verbal cues ("Ready, Set, Go")
  - Tactile cues ("This part of your body has to curl up . . . " while patting stomach muscles)
  - Visual models
  - Enhanced sensory input
  - Repetition of task
- What assistance encourages the best quality movements?
  - Enhanced sensory input
  - Peer imitation
  - Specific verbal cues
  - Specific visual cues
  - Specific tactile-kinesthetic, hand-over-hand cues
  - Rhythmical music, beat or verbal cues
- What assistance is needed to facilitate adaptation of an activity?
  - Help to recognize that a plan is not working
  - Ability to accept help when a plan is not working
  - Assistance with problem-solving to make the plan more successful
  - Help to adapt the idea, plan, or motor response
  - Humor to increase acceptance of error
  - Ability to shake it off and try new things

Vestibular-Proprioceptive Discrimination: Postural-Ocular Control

The vestibular and proprioceptive systems are responsible for understanding body position in and movement through space, maintaining posture, and maintaining a stable visual field. Poor discrimination of vestibular and proprioceptive sensation is manifest in several ways but most commonly as difficulty with postural control: stabilizing or adjusting the body to meet the demands of a task or a changing environment (Miller et al., 2007; Smith Roley et al., 2015). Postural control is both tonic, needed for stability, and dynamic, needed for responding to changes in the environment.

Developing Tonic Postural Control

Tonic postural control depends on interplay between flexor and extensor muscles; it begins to develop in infancy, first in neck extensor muscles and proceeding to trunk extensors. Flexion balances extension, developing slightly later but in a similar pattern. Children with sensory-integrative-based postural-ocular difficulties very commonly have poor tonic postural control (i.e., proximal stability). Because effective and efficient movements depend on a stable postural base, development of tonic postural control is often a good starting point for intervention.

Intervention to improve tonic postural control includes enhanced vestibular and proprioceptive sensations and challenges to posture. We match the characteristics of enhanced sensation with the desired postural response. Activities incorporate linear vestibular input and resistance to movement. Linear movement can occur in any plane: anterior or posterior (e.g., swinging to and fro); horizontal (e.g., swinging side-to-side); or vertical (e.g., bouncing). Resistance to active extension or flexion generates proprioception.

Prone and supine are not only the earliest developmental positions but also the positions in which gravity provides the greatest resistance to extension and flexion, respectively. Thus, a substantial amount of intervention to develop tonic postural control occurs in these two positions.

Promoting Tonic Extension

The prone position includes more than simply lying flat on the belly, head down. As extensor tone develops, children lying prone are increasingly able to hold the head and upper trunk to a relatively vertical position. Creating activities that follow the developmental sequence associated with the prone position provides a way of grading extension.

Lying prone, propped on forearms while on a moving glider swing and blowing cotton balls off raised mats in front is a good starting place for young children or children with very poor postural extension; the activity provides linear vestibular input and demands a relatively easy postural response. Activities that involve weight shifting while moving in a prone-on-elbows position (e.g., taking weight off one arm to reach for and smear shaving cream on a mirror) increase the need for stability but also provide vestibular input.

Bouncing while prone in a frog swing (Fig. 13-19) and holding the head up against gravity provides very strong vestibular input (from movement up and down) and proprioceptive input (from resisting the pull of gravity). Initially, a child may need to position the frog swing across the upper chest to provide a stable base for extending the head. As extension strengthens, the swing can be moved across the stomach to increase the challenge to extensor muscles. A net or spandex hammock also can be used, and positioned similarly on the body, to promote extension. Keep in mind that if the net or hammock swing supports the entire body, there will be little challenge to postural extensors.

Activities that require maintaining the upper and lower body in full extension (i.e., prone extension) provide considerable challenge to

FIGURE 13-19 Bouncing while prone in a frog swing. *Photo courtesy of Sensory Gym.*

tonic postural extensor muscles and trunk stability. Engaging in activity that involves riding a dual swing, hammock, or scooter board down a ramp in prone for vestibular input is a good example (Figs. 13-20 and 13-21). Keeping the trunk in alignment without a sagging trunk is difficult.

Engaging in activities that require moving in and out of full extension are even more difficult than maintaining extension because of the

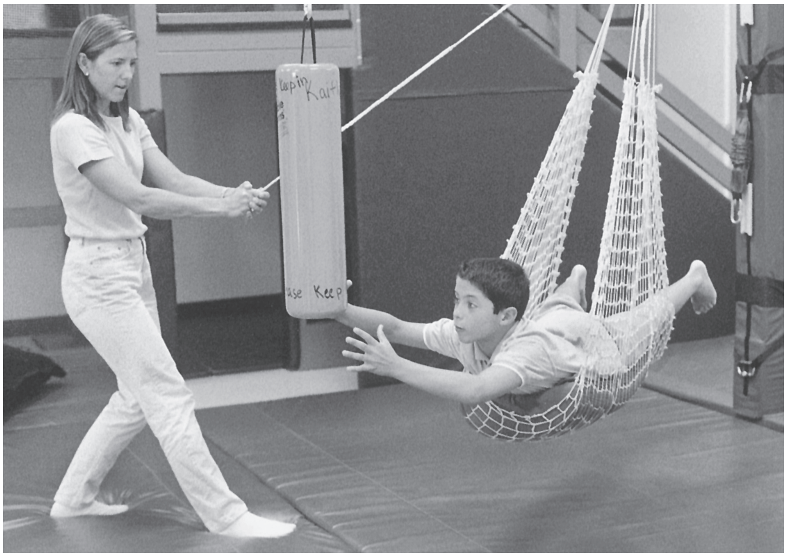


FIGURE 13-20 Hitting a punching bag while swinging requires careful sequencing of several movements. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-21 Riding prone on a scooter board down a ramp in order to "steal jewels from the queen's castle." *Photo courtesy of Shay McAtee, printed with permission.*

requirement for both eccentric and concentric muscle contractions. An example of such an activity is "net basketball" where a child and a therapist (or another child) lie prone in net swings suspended 5 to 6 feet (2 meters) apart, grab bean-bags from the floor, and attempt to throw them onto one another's back—while avoiding any landing on them.

Activities that involve weight shifting on extended arms while maintaining extension of the head and trunk (e.g., lying over a small therapy ball or barrel to place objects on a magnetic board) often must be done on a stable surface (Fig. 13-22). However, the child may exhibit increased difficulty maintaining extension without vestibular input derived from a moving surface.

Promoting Tonic Flexion

When promoting tonic flexion, create activities in supine, provide vestibular input to promote neck flexion, and carefully grade the demand for flexion. For young children or those who have very low tone in the neck and abdominal muscles, intervention begins with activities requiring flexion of only the head and upper trunk. For example, the child lies supine on a wedge, blowing bubbles through a wand held in position by the therapist to encourage slight neck flexion and chin tucking or lying supine in a hammock with the head and neck outside the hammock (Fig. 13-23). The therapist can facilitate neck and upper chest flexion by placing a hand on the child's upper chest and exerting gentle pressure in a caudal direction. Blowing in and out typically encourages neck flexion, but some children hyperextend the neck (lead with the chin) when lifting the head toward the bubble wand. Careful observation, as always, is needed. Further, activities such as this, completed with the child in a stable position, do not provide vestibular input, which might help to facilitate neck flexion.

Activities that require flexion of the legs and lower trunk (e.g., kicking from supine) can also facilitate flexion of the upper trunk and neck (Fig. 13-24). Begin with the child's head and upper trunk fully supported on a wedge. The therapist lowers, rolls, or tosses a large lightweight ball toward the child, who flexes knees and hips in preparation and then extends them to kick the ball. After a while, the child usually lifts his or her head to see the ball. As flexion improves, the child can lean back and prop on elbows without need of the wedge, increasing the demand for neck and abdominal flexion. Again, when working in a static and stable position, vestibular input, which might facilitate neck flexion, is not incorporated.

FIGURE 13-22 "Walking" forward while prone on a barrel to place objects on a magnetic surface. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-23 Lying supine with the head tilted to provide unique input to the semicircular canals. *Photo courtesy of Shay McAtee, printed with permission.*

Whole body flexion can be promoted by creating activities that involve movement on a swing while "hugging" a surface. Hugging a gently moving bolster swing while lying prone on top of the swing or sitting and hugging the center post of a gently moving flexion disc swing or t-swing (Fig. 13-25) may be enough to challenge a child who has very poor flexion. As flexion improves, the intensity (speed and extent) of the swing's movement can be increased, resulting in greater resistance to flexion and more proprioceptive

FIGURE 13-24 Kicking a large ball from a supine position encourages flexion of the legs and trunk. *Photo courtesy of Sensory Gym.*

FIGURE 13-25 Hugging the bolster swing while preparing to fall into a pillow. *Photo courtesy of Shay McAtee, printed with permission.*

input. Lying in a supine flexion position on a bolster swing or on a scooter board and pulling along a rope suspended from both walls, approximately 2 feet above the floor, can also be very challenging with regard to sustained flexion.

Swings suspended from a vertical stimulation device (i.e., several lengths of bungee cord) are particularly useful for facilitating flexion. The bungee cord allows a therapist to vigorously bounce the swing, creating a situation in which the child must hold on tightly in order not to fall off (Fig. 13-26). Proprioceptive input, provided by the bungee cord, coupled with vestibular input gained from the movement helps facilitate flexion. A flexion disc swing (Fig. 13-27) provides a relatively stable base of support, whereas a T-swing offers less and thus requires greater flexor control. Holding onto a moon swing (Fig. 13-28) while throwing a beanbag at a target provides an even greater challenge to both flexion and bilateral integration.

As flexion improves, additional movement from equipment or another external source can be incorporated. When "riding the whale," a child lies prone on top of a bolster swing as the therapist swings it back and forth, sometimes shaking it for added resistance to flexion. The therapist and child can narrate a story where the movement of the swing changes depending on whether there are "clear skies" or "rough seas." This activity can be great fun, but also it can be difficult and over-stimulating. Therefore, the therapist and child need to work out ways to give the child control; one way is to develop code words to make the whale go "kooky" or "stop."

A "bucking bronco" game, which involves hugging a fast-moving tire inner tube that the therapist shakes, is an even greater challenge to flexion (Fig. 13-29). In both "riding the whale" and "the bucking bronco," a child sometimes falls off the swing as the therapist shakes it. Thus, it is important to have sufficient padding (e.g., dense mats, crash mats, pillows) surrounding the excursion of the swing. Ayres (1977) indicated that, once children developed adequate flexion, many enjoy activities that involve falling such as releasing the bolster swing and falling onto the crash pads below.

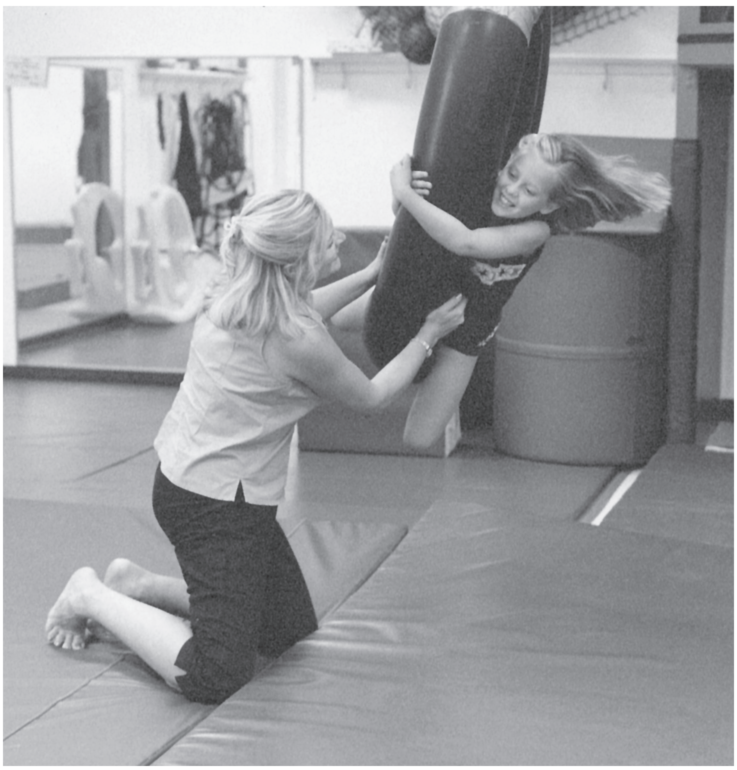


FIGURE 13-26 A rough ride on an inner tube swing. *Photo courtesy of Shay McAtee, printed with permission.*

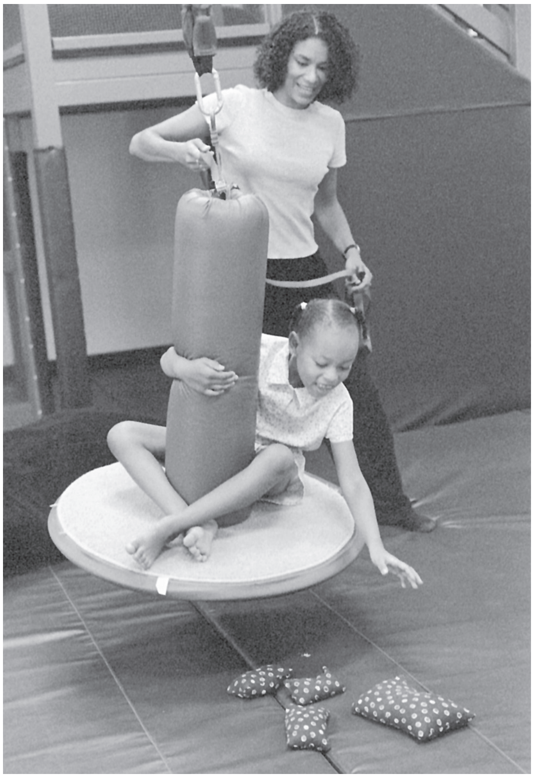


FIGURE 13-27 The disc swing. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-28 Moon swing. *Photo courtesy of Shay McAtee, printed with permission.*

FIGURE 13-29 Hugging a tire inner tube that the therapist pushes or shakes challenges flexion. *Photo courtesy of Sensory Gym.*

Promoting Dynamic Postural Control

Although prone and supine are excellent positions for developing extension and flexion, children also need dynamic postural control when moving into other positions or transitioning between positions. Dynamic postural control is necessary for activities such as rolling (Fig. 13-30), kicking, or catching a ball; these activities involve trunk rotation and anticipatory actions. Dynamic postural control requires interplay between flexion and extension. Anticipatory actions also promote motor planning. The need to cross the body midline, which often accompanies trunk rotation, promotes bilateral integration. The previously described activities that involved an unstable "environment," including the "bucking bronco" and riding on a flexion-disc swing, challenge dynamic postural control as the child strives to stay on the piece of equipment.

Promoting Righting and Equilibrium

An important purpose of dynamic postural control is to offset environmental events that might otherwise result in loss of balance or allow changes in body position (e.g., transitioning from sitting to hands and knees). Equilibrium reactions are rapidly occurring limb reactions that help to maintain body mass over the base of support. Equilibrium reactions co-occur with righting responses, which keeps the head and trunk aligned. Activities that promote righting and equilibrium (Fig. 13-31) involve rapid angular

FIGURE 13-30 Rolling in an inflatable barrel to encourage rotation. *Photo courtesy of Southpaw Enterprises.*

FIGURE 13-31 Balancing on a large inner tube while play fighting with foam bats. *Photo courtesy of Shay McAtee, printed with permission.*

(including orbital or rotational) movements.[4] Because the hair cells of the semicircular canals responsible for equilibrium are stimulated during acceleration and deceleration, activities should include frequent starts and stops and changes in direction and speed.

When we hang a swing from a single suspension point, we promote angular movement. Many commercially available swings are designed to be hung from one point: the frog swing, platform swing, net swing, dual swing, flexion disc, and t-swing (see Appendix to the chapter). Other swings designed to be hung from two points, such as the bolster swing, also can be hung from a single point. Swings suspended by two points can also generate angular movement when the swing moves in an arc, as happens, for example, when the ropes are short or the swing moves side-to-side.

To promote equilibrium, create activities in various positions (i.e., prone, sitting, quadruped, kneeling, and standing) that require small, rapid adjustments such as to prevent falling when jostled. These can involve any piece of equipment that moves or any activity that involves reaching a distance away from the body. Activities that involve a narrower base of support, greater movement of the support surface, or reaching a long distance require greater stabilization of trunk muscles (i.e., tonic postural control). Our goal is to create activities that challenge both dynamic and tonic postural control but can be accomplished with automatic, fluid responses.

Activities that involve changing head movements to pick up beanbags or balls (see Fig. 13-27) from a mat underneath the swing, passing objects sideways or over the head to another, or batting at suspended objects while swinging also inherently involve angular motion and promote righting. Any activities that involve moving from one position to another or transferring from one piece of equipment to another also promotes righting responses and, when balance is threatened, equilibrium.

Promoting Ocular Control

Children with sensory integrative dysfunction often have difficulty both with reflexive eye movements (e.g., PRN) and with moving the eyes independently of the head to follow a target or scan the environment. Automatic reflexive movements that help to maintain a stable visual field depend on the vestibular and proprioceptive systems, whereas **ocular tracking** depends on the visual system (Purves et al., 2012).

Activities that incorporate dynamic postural control and projected action sequences also promote ocular control. Almost all total body movements and motion on any swing stimulate reflexive eye movements that provide a stable visual field. Throwing beanbags accurately at a moving target (e.g., a plastic bottle disguised as an "alien spaceship"), for example, involves producing visually controlled ocular movements (e.g., smooth pursuits and quick localization) and moving the eyes separately from the head. Activities where both the child and target are moving (Fig. 13-32) promote both reflexive eye movements and ocular tracking, but they are at a more challenging level of ocular-motor control. For young children or those with very poor ocular motor control, begin with activities that include attaining objects through reaching before progressing to throwing at a target (Fig. 13-33). When starting at this level initially, present objects at midline and slowly extend the visual range to the sides, upward, and downward, and finally behind the child. Some children with poor ocular motor control may benefit from a systematic approach designed by, or in conjunction with, a developmental optometrist who specializes in ocular motor training. Mary Kawar's programs

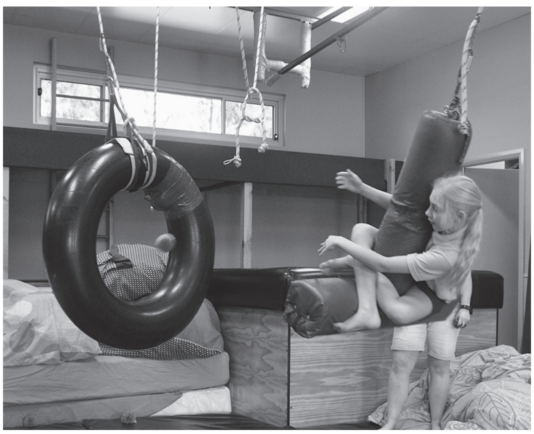


FIGURE 13-32 Activities where both child and target are moving challenge ocular control as well as timing. *Photo courtesy of Sensory Gym.*

[4]Always use angular vestibular input with caution because it is extremely powerful.

FIGURE 13-33 Blowing bubbles through a long straw. *Photo courtesy of Shay McAtee, printed with permission.*

in Chapter 18 (Complementary Programs for Intervention) also address ocular motor control.

Targeting Other Aspects of Proprioceptive-Vestibular Discrimination

Children who experience difficulty discriminating vestibular and proprioceptive sensations may have trouble distinguishing head or body orientation in space. At the extreme, they may not know intuitively whether they are right side up or upside down. However, more often, they have difficulty recognizing an exact vertical. In intervention, emphasize activities that provide linear movement (i.e., otolithic input). Many of the previously described activities for children experiencing gravitational insecurity can be useful. However, unless children *also* have modulation dysfunction, we typically are able to incorporate more movement and larger excursions. Activities usually involve suspended equipment to facilitate a variety of head positions (e.g., prone, supine, sitting). Because linear movement is desired, swings are generally suspended from two points. Try to incorporate opportunities for vertical movements and being upside down because of the less common occurrence of those in everyday life. Jumping and riding a swing suspended by a bungee cord are ways to enhance both proprioception and vertical movement.

Children who have difficulty with proprioceptive discrimination often have trouble judging the appropriate amount of muscle force to exert. They may press too hard with a pencil or push too hard in a game of tag (as Sam does); knock over objects because they misjudge the force needed when reaching; and "sound like an elephant" when walking down the hall or the stairs. Enhanced proprioception is essential to promoting discrimination. Emphasize activities that provide resistance to active movement (i.e., heavy work). Input can be provided through the muscles of the mouth, neck, trunk, arms, and legs. The weight of the body against gravity ensures that many activities that involve swings, a scooter board, or a trampoline provide resistance to body movements. Heavy work from resistance (e.g., pushing, pulling, jumping on a trampoline) and weight-bearing positions (e.g., quadruped) provide enhanced proprioception. Other examples include pulling a stretchy rope to move a swing or propel a scooter board as well as moving through a spandex hammock or ball pit. As with all interventions based on SI theory, active participation in meaningful tasks is crucial. Table 13-6 has a variety of suggestions for enhancing proprioceptive input. All these suggestions would be appropriate for Sam.

Although enhanced proprioception is essential to promoting discrimination, activities that require judging and adjusting force also are important; for example, blowing or flicking cotton balls or ping pong balls to targets located various distances away, playing catch with a ball made of foam soap without squashing it, or tossing balls or beanbags into a hoop or relatively small targets placed at varying distances.

Promoting Increased Tactile Discrimination

Children with poor tactile discrimination generally come to the attention of a therapist because of difficulties with praxis (Ayres, 1972; May-Benson, 2014) or fine motor skills rather than as a primary problem. Nonetheless, increased tactile discrimination is an important

TABLE 13-6 Proprioceptive Activities

Pushing, Pulling, and Carrying
• Pushing heavy objects, grocery cart, and so on • Pulling ropes tied to large beanbags • Burrowing under large pillows • Pushing a therapy ball through a spandex tunnel • Carrying books, boxes, heavy objects • Tug of war, push of war
Oral Motor Activities
• Sucking a resistive substance through a straw • Chew toys or objects • Chewing gum or chewy, crunchy foods
Movement Activities
• Jumping, bouncing • Pulling oneself up (bending arms while pulling) on a jungle gym or ladder • Holding oneself actively on (with bent arms) and riding a trapeze or zip line • Pulling a rope or pushing off a vertical surface with feet while swinging • Making a swing or scooter board go by pulling a stretchy rope or tire inner tube

TABLE 13-7 Activities to Encourage Tactile Discrimination

Providing Enhanced Tactile Input
• Moving in a large container of plastic balls or ball pit • Crawling or burrowing under textured pillows • Painting and drawing in shaving cream, foam soap, and finger paint • Moving hands and arms through a bin filled with beans, rice, or macaroni (generally to find an object) • Playing with a massager or vibrating toy • Using a vibrating toothbrush • Blowing kazoos or whistles • Blowing through a straw to create a bubble mountain
Promoting Tactile Discrimination
• Identifying objects hidden in a container using only touch (stereognosis) • Identifying letters or shapes drawn on the back • Describing or identifying objects placed under clothing (e.g., a beanbag under a shirt)

goal of intervention as it is thought to underlie body scheme and motor planning.[5]

Promoting increased tactile discrimination involves enhanced tactile and proprioceptive sensations as well as activities that ask a child to distinguish the temporal and spatial qualities of touch (e.g., matching objects according to tactile qualities). Utilizing a variety of different shapes, sizes, and textures can provide enhanced tactile input, and can also be used to incorporate opportunities for matching and labeling. For Sam, finding objects (Fig. 13-34) hidden in a mixture of dried macaroni, beans, corn, lentils, and rice presented a substantial challenge to tactile discrimination. Table 13-7 provides a variety of tasks that provide enhanced tactile input (primarily deep pressure) and encourage tactile discrimination.

Because children with poor tactile discrimination often have decreased body scheme, games such as hide and seek can be a challenge.

FIGURE 13-34 Digging for objects buried in a box filled with dried beans. *Photo courtesy of Shay McAtee, printed with permission.*

[5]Many children with poor tactile discrimination also have deficits in vestibular and proprioceptive processing. (See Chapter 5: Praxis and Dyspraxia.) Therefore, intervention for poor tactile discrimination is usually done in conjunction with other sensory systems and related to the end product of praxis. (See also section on intervention for promoting praxis in the previous text.)

Children may believe they are hidden completely when, in fact, they are only partially hidden. Hide and seek can help children to utilize cognitive strategies to compensate for poor discrimination.

HERE'S THE POINT

- Poor discrimination of vestibular and proprioceptive sensations can manifest as poor tonic or dynamic postural control, poor ocular control, and trouble distinguishing head or body orientation in space.
- Interventions to improve postural control may include enhanced vestibular and proprioceptive sensations, challenges to posture and equilibrium, and transitions into and out of various positions.
- Promoting increased tactile discrimination involves enhanced tactile sensations, and often deep pressure touch and proprioception.

Balancing Intervention for Multiple Types of Sensory Integrative Dysfunction

Some children have difficulty with both modulation and praxis. For example, a child could have tactile defensiveness, gravitational insecurity, and SD. All problems must be addressed in intervention—often within the same session. Until and unless a child establishes, and can maintain, a functional level of arousal, it is difficult to make significant changes in postural-ocular control, bilateral integration, or motor planning. A child with tactile over-responsivity may not be able to interact with tactile media that could support improved discrimination. Children with gravitational insecurity may be so fearful of moving that it is impossible to engage them in activities that provide enhanced vestibular input. Further, gravitational insecurity may mask poor discrimination of head position in space and postural-ocular difficulties, such as delayed righting. Thus, modulation is a top priority within and across sessions. Interspersing activities that provide enhanced sensation with those that are calming may prevent some children who have both praxis and modulation difficulties from becoming so overly active that their behavior deteriorates.

PRACTICE WISDOM

Throughout this chapter, we present a variety of activities that can be used to improve performance of children with specific sensory integrative disorders. However, it takes a trained and practiced clinician to implement these activities at the right time, in the right way, with the right child. SI therapy requires constant monitoring of the child's level of interest and arousal as well as the challenge of the task (i.e., too difficult or too easy) and then changing features within the environment. Therefore, a clinician cannot walk into a session with a set plan for how the hour will go. Rather, he or she needs to gauge the specific needs of the child continuously within the context of the child's goals and desires. This can be challenging for new therapists or for therapists who have not had appropriate training or mentorship in SI theory and intervention. Videotaping therapy sessions (with child and caregiver permission) can be a useful strategy for new clinicians to learn about their own therapeutic strengths and weaknesses. After watching themselves during treatment, therapists often will state things such as: "I'm talking way too much," "He (the child) was not into that activity at all; I should have made it more fun," or "That activity was too easy—I could have moved the target and then he would have had to cross midline." Ideally, the therapist will have a mentor to review the videos with; but even without a mentor, the exercise of critiquing one's own therapy sessions can be a useful learning tool for therapists learning to use an SI approach.

Practical Considerations for Intervention

Sensory integrative theory is complex and continually evolving. Sound understanding of the theory, and the ability to translate it to practice, are essential to providing safe, effective, state-of-the-art intervention. The Fidelity Measure developed by Parham and colleagues (2007, 2011) lists structural elements for evaluating research into ASI therapy. These same elements provide guidance to therapists in the implementation of ASI in practice. We discuss these elements and some additional practical factors. See also Chapter 14 (Distilling Sensory Integration Theory for Use: Making Sense of the Complexity), which contains the Fidelity Measure.

Parent Involvement

Many parents become involved actively in direct intervention sessions. Such involvement can lead to a special bond between child and parent and assist both parent and therapist to develop new strategies for interacting effectively with a child. Miller and colleagues refer to "magic moments"—times when a child first achieves something new in therapy. Having parents actively engaged in such moments is a way of "sharing the magic." See text Appendix: The STAR Process: An Overview. Nonetheless, it is important that parents not try to modify their child's behavior in therapy, thereby disrupting the session.

Therapist Training

In the Fidelity Measure, Parham and colleagues (2007, 2011) specified specialized, post-professional education, such as SI certification, as well as mentoring from an expert. This education base provides a foundation for the clinical reasoning required to implement ASI. Attending continuing education presented by experts and reading current research are excellent ways to stay abreast of current thinking and research related to SI. Mentoring from an expert in treating disorders of SI can be invaluable.

Therapist-to-Client Ratio

Implementing ASI requires constant vigilance and adaptation to meet a child's changing needs and ensure successful participation. Because each child is different, it is very challenging, if not impossible, for a single therapist to provide ASI to more than one child at a time. However, it can be beneficial to have more than one therapist, each working with one child, sharing a therapy space. The interactions among children may contribute to problem-solving, planning, and negotiation, all valuable social skills.

Length of Sessions

Length of sessions can be determined by a variety of factors, including the age and profile of the child, the setting, and the pragmatics of reimbursement. For children whose modulation issues interfere with attaining and maintaining a functional level of arousal, we need to allow enough time to establish a state of optimal, or near-optimal, arousal. As a child becomes capable of increasingly complex adaptive responses, it is helpful to have a long enough session to develop and adapt activities sufficiently. Further, because the aim of occupational therapy is for children to develop and better manage the challenges of everyday life, we also may need time to work on specific skills (e.g., shoe tying, trying new foods, or bicycle riding). In our experience, an ideal session length is 45 to 60 minutes.

Physical Environment

In the Fidelity Measure, Parham and colleagues (2007) clearly described the importance of a space that is big enough and configured in such a way as to support the physically active play characteristic of sensory integrative intervention. A room size of at least 12 feet (4 meters) square is needed, but a space that is 14 x 20 feet (5 x 7 meters) is ideal as it ensures safety during large excursions of a swing and provides flexibility for arranging equipment. To ensure emotional and physical safety, the floor must be covered with mats; additional soft cushions or pillows are useful. At least one small quiet space should be available.

Suspension System

A treatment space should have at least three suspension points placed in a line with a minimum distance of 2.5 to 3 feet (1 meter) between. This allows for combining equipment (e.g., swinging on a trapeze to jump through two suspended inner tubes, bumper tires, swinging while throwing at a suspended target). A rotational device and strong bungee cords on one or more suspension points allow the maximum range of movement of equipment.

Installing a suspension system correctly is essential to safety. Suspension systems must sustain a minimum working load of 1,000 pounds. Although many children weigh fewer than 100 pounds, when they bounce and orbit on a piece of suspended equipment the shearing forces on the suspension system are tremendous. Further, adults or other children often are part of activities on the equipment, increasing the demand on the system.

Southpaw Enterprises (https://www.southpaw.com/safety-tips/) publishes a guide for installing a suspension system in the ceiling. When installing a suspension system, contact a structural engineer or contractor with a background in design. Even then, you will likely have to explain the need for a system that supports such a large working load. Consultants often incorrectly assume that a structure similar to an outdoor swing set is sufficient—and it is not.

Suspension points must be high-grade forged steel eyebolts (indicated by a fully closed circle on the eyebolt) installed *through* support beams and *locked* securely with nuts and washers. *Never hang equipment from eyebolts screwed directly into the ceiling without going all the way through a part of the ceiling structure and locking, even with lag bolts or bolts that expand as they are tightened.* Only bolts that go all the way through (i.e., throughbolts) and are locked on the other side can safely support the strong shearing forces generated by suspended equipment. In addition, rotational devices should be used with any piece of equipment that orbits or rotates in order to minimize the torque on the ceiling suspension point from which it is hung.

Commercially available, freestanding suspension systems can be used in places where a ceiling system cannot be installed. Large, heavy, non-portable systems with a working load of 1,000 pounds are preferred (see also Koomar, 1990). Many lightweight, portable systems have a working load of fewer than 1,000 pounds. These systems are limited as far as the type of activity that can be done on them.

Equipment and Storage

Enhanced sensation, a basic element of ASI, depends on access to a variety of swings, bouncing equipment (e.g., therapy ball, mini-trampoline), ropes for pulling, weighted objects, spandex fabric and tactile mediums, vibrating toys, visual targets, and props to support engagement in play (Parham et al., 2011). Equipment must be stored in such a way as to minimize the chances of injury from tripping or falling and to prevent the space from being so cluttered that children become distracted.

Summary and Conclusions

Direct intervention based on SI theory can be powerful for effecting change but implementing intervention effectively is challenging. This chapter is devoted to meaningful activities in which enhanced sensation is matched with the characteristics of desired adaptive interactions, established through rigorous ongoing assessment. Throughout a session, the therapist continuously observes the child's responses and alters activities without disrupting the overall flow.

The most effective therapy is a marriage of science and art. Interweaving the two enables a therapist to engender trust and facilitate increasingly complex adaptive responses. A hallmark of sensory integrative therapy is that it is child-directed. Child-directedness is a complex concept, closely aligned to the art of therapy. (See also Chapter 12, The Art of Therapy.) At the very least, child-directedness involves co-creating activities and ensuring success. But success does not mean that children never miss a target or fall off equipment onto a mat. Total, 100% success in every attempt would be boring and would not result in improved SI or greater skill. The just-right challenge, which requires children to work at the edge of their capabilities, is an important hallmark of sensory integrative therapy.

Direct SI therapy should always be provided concurrently with coaching to parents and other caregivers, and, whenever possible, direct involvement of the caregivers in therapy sessions. Practitioners communicate with caregivers to help them understand the daily life effects of sensory integrative dysfunction and develop strategies to minimize negative effects. Caregiver input into goals and priorities for therapy must also be a part of creating SI intervention. Therapists will also regularly check in with caregivers to assure that the effects of intervention are positive, make adjustments as needed, and facilitate generalization of newly acquired skills. Best practice dictates that all therapy is goal driven and addresses daily life demands. Together, the child, caregivers, and therapist monitor progress toward the goals to ensure that the child has generalized skills and abilities for everyday life and feels competent doing them. Based on the result of these assessments, the team recommends a time when intervention should be discontinued. (See also Chapter 17, Using Sensory Integration Theory in Coaching.)

Where Can I Find More?

Ayres, A. J. (2005). *Sensory integration and the child: 25th anniversary edition.* Torrance, CA: Western Psychological Services.

This seminal resource by A. Jean Ayres outlines the underlying theory of sensory integration and how sensory integration therapy can be used to ameliorate underlying differences in neurological functioning.

Mailloux, Z., & Schaaf, R. C. (2015). *Clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism.* Bethesda, MD: AOTA Press.

This research-based resource provides a step-by-step guide to implementing ASI for children with autism. Features include how to set goals, conduct the intervention, and evaluate treatment outcomes.

References

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1977, March). Developmental dyspraxia. Symposium conducted in Dayton, Ohio.

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1985). *Developmental dyspraxia and adult-onset apraxia.* Torrance, CA: Sensory Integration International.

Boyer, F. C., Percebois-Macadréa, L., Regrain, E., Lévêquec, M., Taïar, R., Seidermannc, L., . . . Chaysc, A. (2008). Vestibular rehabilitation therapy. *Clinical Neurophysiology, 38*(6), 479–487. doi:10.1016/j.neucli.2008.09.011

Case-Smith, J. (2010). An overview of occupational therapy for children. In J. Case-Smith & J. C. O'Brien (Eds.), *Occupational therapy for children* (6th ed., pp. 1–21). Maryland Heights, MO: Mosby.

Cohen, H. S. (2000). Vertigo and balance disorders: Vestibular rehabilitation. *OT Practice, 5,* 14–18.

Fisher, A. G., & Bundy, A. C. (1989). Vestibular stimulation in the treatment of postural and related disorders. In O. D. Payton, R. P. DiFabio, S. V. Paris, E. J. Protas, & A. G. Van Sant (Eds.), *Manual of physical therapy techniques* (pp. 239–258). New York, NY: Churchill Livingstone.

Gerber, R. J., Wilks, T., & Erdie-Lalena, C. (2010). Developmental milestones: Motor development. *Pediatrics in Review, 31,* 267–277.

Hanft, B., Miller, L., & Lane, S. (2000, September). Towards a consensus in terminology in sensory integration theory and practice: Part 3: Observable behaviors: Sensory integration dysfunction. *Sensory Integration Special Interest Section Quarterly, 23,* 1–4.

Herdman, S. (1994). *Vestibular rehabilitation.* Philadelphia, PA: F.A. Davis Co.

Kawar, M., Frick, S., & Frick, R. (2005). *Astronaut training: A sound activated vestibular-visual protocol for moving looking and listening.* Madison, WI: Vital Links.

Keogh, J., & Sugden, D. (1985). *Movement skill development.* New York, NY: Macmillan.

Koomar, J. (1990). Providing sensory integration therapy as an itinerant therapist. *Environment: Implications for occupational therapy practice.* Rockville, MD: American Occupational Therapy Association.

Lane, S., Miller, L., & Hanft, B. (2000). Towards a consensus in terminology in sensory integration theory and practice: Part 2: Sensory integration patterns of function and dysfunction. *Sensory Integration Special Interest Section Quarterly, 23,* 1–3.

Lane, S. J., Smith Roley, S., & Champagne, T. (2013). Sensory integration and processing: Theory and applications to occupational performance. In B. Schell, G. Gillen, & M. Scafa (Eds.), *Willard & Spackman's occupational therapy* (12th ed., pp. 816–868). Philadelphia, PA: Lippincott, Williams, & Wilkins.

Magalhaes, L. C., Koomar, J. A., & Cermak, S. A. (1989). Bilateral motor coordination in 5- to 9-year-old children: A pilot study. *American Journal of Occupational Therapy, 43,* 437–443.

May-Benson, T. (2001). A theoretical model for ideation. In S. Smith Roley, E. I. Blanche, & R. C. Schaaf (Eds.), *Understanding the nature of sensory integration with diverse populations* (pp. 163–181). Austin, TX: Pro-Ed.

May-Benson, T. (2014.). Praxis disorders. In C. Murray-Slutsky & B. S. Paris (Eds.), *Autism interventions: Exploring the spectrum of autism* (pp. 215–243). Austin, TX: Hammill Institute on Disabilities.

May-Benson, T., & Koomar, J. (2007). Identifying gravitational insecurity in children: A pilot study. *American Journal of Occupational Therapy, 61,* 142–147.

Miller, L. J., Anzalone, M., Lane, S., Cermak, S., & Olsten, E. (2007). From the guest editor: Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy, 61,* 135–140.

Miller, L. J., McIntosh, D. N., McGrath, J., Shyu, V., Lampe, M., Taylor, A. K., . . . Hagerman, R. J. (1999). Electrodermal responses to sensory stimuli in individual with fragile X syndrome: A preliminary report. *American Journal of Medical Genetics, 83,* 268–279.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration research. *American Journal of Occupational Therapy, 61,* 216–227.

Parham, L. D., Smith Roley, S., May-Benson, T., Koomar, J., Brett-Green, B., Burke, J., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on the effectiveness of the Ayres Sensory Integration® intervention. *American Journal of Occupational Therapy, 65,* 133–142. doi:10.5014/ajot.2011.000745

Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A.-S., & White, L. E. (2012). *Neuroscience* (5th ed.). Sunderland, CT: Sinauer Associates, Inc.

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism and Developmental Disorders, 38*(3), 516–529.

Richter, E., & Oetter, P. (1990). Environmental matrices for sensory integrative treatment. *Environment—Implications for occupational therapy practice, a sensory integrative perspective.* Rockville, MD: American Occupational Therapy Association.

Schoen, S., Miller, L. J., Brett-Green, B., & Nielsen, D. (2009). Physiological and behavioral differences in sensory processing: A comparison of children with autism spectrum disorder and sensory modulation disorder. *Frontiers in Integrative Neuroscience, 3,* 1–11. doi:10.3389/neuro.07.029.2009

Schoen, S., Miller, L. J., & Sullivan, J. C. (2014). Measurement in sensory modulation: The sensory processing scale assessment. *American Journal of Occupational Therapy, 68,* 522–530.

Seidler, R. D., Noll, D. C., & Thiers, G. (2004). Feedforward and feedback processes in motor control. *NeuroImage, 22,* 1775–1783.

Smith Roley, S. (2006). Planning intervention: Bridging the gap between assessment and intervention. In R. Schaaf & S. Smith Roley (Eds.), *Sensory integration: Applying clinical reasoning to practice with diverse populations* (pp. 37–62). Austin, TX: Pro-Ed.

Smith Roley, S., Mailloux, Z., Miller-Kuhaneck, H., & Glennon, T. (2007). Understanding Ayres Sensory Integration®. *OT Practice, 12,* CE-1-CE-8.

Smith Roley, S., Mailloux, Z., Parham, L. D., Schaaf, R. C., Lane, C. J., & Cermak, S. (2015). Sensory integration and praxis patterns in children with autism. *American Journal of Occupational Therapy, 69,* 1–8.

Stackhouse, T. M. (2014). The adaptive response to the just right challenge: Essential components of sensory integration intervention. *Sensory Integration Special Interest Section Quarterly, 37,* 1–4.

Wang, Z., Magnon, G. C., White, S. P., Greene, R. K., Vaillancourt, D. E., & Mosconi, M. W. (2015). Individuals with autism spectrum disorder show abnormalities during initial and subsequent phases of precision gripping. *Journal of Neurophysiology, 113,* 1989–2001.

Williams, H. G. (1983). *Perceptual and motor development.* Englewood Cliffs, NJ: Prentice Hall.

APPENDIX **13-A**

List of Vendors and Equipment

COMPANY	FLOOR EQUIPMENT	SUSPENDED EQUIPMENT
Southpaw Enterprises	Crash mats	Linear platform glider
	Air mattress	Bolster swing
	Ball pit and balls	Square platform
	Barrel	Tire inner tube (tube swing)
	Fold and go trampoline	Rubber dual swing
	Bounce disc	Flexion disc
	Spiral floor disc	Flexion t-swing
	Foam blocks	Moon swing
	Body sox	Net swing
	Scooter board ramp	Tadpole (frog) swing
	Scooter board	Cuddle swing
	Massagers	Acrobat swing (spandex hammock)
	Weighed vests, toys	Purple people eater swing
		Trapezes
		Vertical stimulation device (bungee cords)
Flaghouse	Floor mats	Circle platform swing
	Wedges	Log (bolster) swing
	Foam platforms and ramps	
	Ball pit balls	
	Air cushion	
	Balance disc	
	Belly bumpers	
	Medicine balls	
	Rings and handles	
Fun and Function	Crash mats	Textured platform swing
	Ball pits and balls	Air-lite raft platform swing
	Whisper tilt and spin	Air-lite seal bolster swing
	Cozy canoe	Skateboard swing
	Foam balance beam	Airwalker
	Hopper balls	Hammock chair
	Tunnels	Net chair

COMPANY	FLOOR EQUIPMENT	SUSPENDED EQUIPMENT
Achievement Products	Floor mats Balance beams Ball pit balls Weighted vests, toys Therapy putty	Flexidisc Net swing Airwalker Vestibulator platform swing Roll (bolster) swing
Therapro	Scooter board Body sox Therapy balls Medicine balls Theraband and tubing Oral motor activities Therapy putty	
Tiffin Athletic Mats	Ramps Octagon	

Achievement Products	(800) 373-4699	www.achievement-products.com
Flaghouse	(800) 793-7900	www.flaghouse.com
Fun and Function	(800) 231-6329	www.funandfunction.com
Southpaw Enterprises	(800) 228-1698	www.southpawenterprises.com
Therapro	(800) 257-5376	www.theraproducts.com
Tiffin Athletic Mats	(800) 843-3467	www.tiffinmats.com

CHAPTER

14

Distilling Sensory Integration Theory for Use: Making Sense of the Complexity

Lucy J. Miller, PhD, OTR/L, FAOTA ■ L. Diane Parham, PhD, OTR/L, FAOTA

If it is true . . . that social reality has . . . [created] new zones of complexity and uncertainty, it is also true that practitioners . . . do sometimes find ways to make sense of complexity and reduce uncertainty to manageable risk.

—Schön, 1983, p. 18

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe three resources that distill Ayres Sensory Integration© (ASI) theory, reducing its complexity for the purpose of guiding the provision and evaluation of direct intervention: the schematic representation of sensory integration (SI) theory used throughout this text, the ASI Fidelity Measure (ASIFM), and the Sensation, Task, Environment, Predictability, Self-monitoring, and Interaction (STEP-SI) model.
- ✔ Describe a problem-solving resource that draws from ASI and helps families develop workable strategies to ameliorate everyday problems associated with poor regulation and modulation: Attention, Sensation, Emotion regulation, Culture, Relationships, Environment, and Tasks (A SECRET).

Purpose and Scope

Occupational therapy practice theories are complex. Because practice demands application of theory, an important day-to-day aim of therapists is to manage complexity (Schön, 1983). Sensory integration (SI) is among the most complex of occupational therapy theories. Thus, it is not surprising that therapists using Ayres Sensory Integration© (ASI) in practice and reading research regarding its effectiveness seek "short cuts" that make the theory and its tenets more accessible. Such short cuts do not provide recipes. Rather, they prompt reasoning and problem-solving critical to planning and reflection.

SI theory offers a way to understand the behaviors of a particular group of children and frame intervention to help ameliorate the problems those children face every day. Therapists also apply SI theory in coaching to help families and teachers reframe children's behavior and adapt tasks and environments so that the children succeed and the parents and teachers feel, and are, more effective in their own roles.

Several theorists, researchers, and practitioners have developed resources to help therapists or families manage the complexity of SI theory in everyday practice. These resources take the form of:

- A conceptual framework illustrating the hypothesized relationship among constructs (i.e., the schematic representation of ASI used throughout this text)

- An instrument to plan direct intervention and evaluate research examining the effectiveness of ASI for congruence with SI theory (i.e., ASI Fidelity Measure [ASIFM])
- A discussion guide for clinical decision-making based on SI theory (i.e., Sensation, Task, Environment, Predictability, Self-monitoring, and Interaction [STEP-SI] model)
- A practice model illustrating a clinical reasoning process developed for families to ameliorate common everyday problems associated with poor regulation and sensory modulation (i.e., Attention, Sensation, Emotion regulation, Culture, Relationships, Environment, and Tasks [A SECRET])

We describe these four resources in the following sections, showing them briefly and reiterating the purpose of each.

Resources to Guide Direct Intervention

Three of the resources that we include simplify ASI for the purpose of creating direct intervention or evaluating the effectiveness of research. These are the schematic representation of SI theory used throughout this text, the ASIFM, and the STEP-SI model.

Schematic Representation of Sensory Integration Theory

Throughout this book, we have utilized a schematic representation of SI theory that illustrates hypothesized relationships among vestibular, proprioception, and tactile sensations and particular types of sensory integrative dysfunction (see Fig. 14-1). In Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), we used this schematic as the basis for creating therapeutic activities that match the type of enhanced sensation with the most logical proximal objectives of therapy. We apply this model to practice by beginning at the center (in the column labeled "Inadequate CNS Integration and Processing of Sensation") and reading either to the left for outcomes related to sensory modulation or to the right for outcomes related to praxis.

HERE'S THE POINT

- The schematic representation of SI theory that we use throughout this book is a model for creating therapeutic activities that match the type of enhanced sensation with logical proximal objectives of therapy. This model depicts the science of SI therapy.

Ayres Sensory Integration® Fidelity Measure (ASIFM)

■ L. Diane Parham, PhD, OTR/L, FAOTA

Although the science of therapy is a critical aspect of ASI, the art of therapy is equally important (see Chapter 12, The Art of Therapy). In fact, arguably, without art, an intervention is not ASI. The schematic representation shown in Figure 14-1 does not capture art and thus does not allow a therapist or a researcher to be faithful to *all* the tenets of ASI.

Parham and colleagues (2007, 2011) referred to *fidelity* as faithfulness to the tenets of ASI. Although the concept of fidelity is most often applied to research testing the effectiveness of ASI, fidelity is also very relevant to practice. This is because fidelity addresses whether the intervention being provided in real-life practice is actually what the provider claims that it is.

The need to make accessible the science and art as well as other important underpinnings (structures) led Parham and colleagues to create the ASIFM. They created and first applied the ASIFM in the context of research. When conducting a systematic review of 61 published, peer-reviewed studies claiming to evaluate the effectiveness of SI intervention, Parham and colleagues found that the descriptions of treatment procedures differed dramatically across studies (Parham et al., 2007). Although all the authors of the studies claimed that their interventions were SI, none addressed the fidelity of their interventions to the tenets of Ayres' theory.

According to experts on outcomes research (Kazdin, 1994; Moncher & Prinz, 1991; Wolery, 2011), fidelity of intervention should be reported and monitored throughout any study of treatment effectiveness in order to demonstrate that the intervention is actually what it claims to be and is provided with a high degree of fidelity

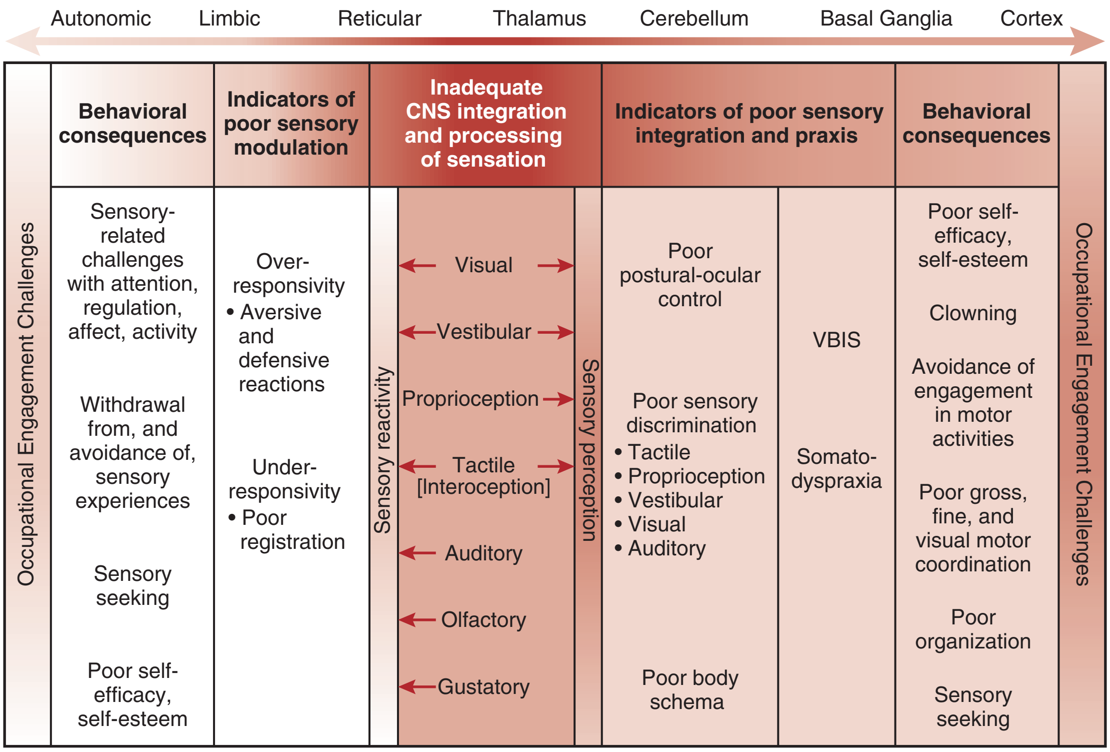


FIGURE 14-1 Schematic representation of sensory integration theory.

PRACTICE WISDOM

Here are a few examples of situations in which the fidelity of ASI intervention is compromised:

- The occupational therapist applies a brushing protocol as the intervention and calls it SI treatment, citing Ayres.
- The occupational therapist provides a weighted vest for the child to wear at intervals during the school day and calls this SI therapy.
- The occupational therapist prescribes a sensory diet of strategies for the teacher or parent to implement throughout the day and calls this SI intervention based on Ayres.

In each of the scenarios listed, fidelity is compromised because the therapist providing the intervention *inaccurately* represented it as ASI. Each of these examples may be a helpful way to intervene in particular cases, but none of these intervention procedures comprises all, or even most, of the concepts of ASI theory; thus, they cannot be called ASI intervention. Although they may be delivered with the best of intentions, such misrepresentations of ASI intervention are problematic because they create confusion among therapists who wish to understand SI, and, perhaps even more disconcertingly, they lead to misunderstandings of ASI theory and practice among other professionals and the public.

to all participants. In order to accomplish this, researchers need to carefully define (a) who is qualified to provide the intervention, and (b) the principles and procedures essential to the intervention. Furthermore, they need to use an instrument to measure fidelity of the intervention in a reliable and valid manner during the intervention phase of the study.

Seeking to systematically evaluate the fidelity to ASI of the 61 effectiveness studies noted previously, Parham and colleagues needed first to identify the key elements of ASI intervention. They addressed two elements:

1. *Process elements,* shown in Table 14-1, which reflect the therapist's use of

TABLE 14-1 Process Elements of the ASIFM

1. Therapist ensures physical safety of child.
   The therapist anticipates physical hazards and attempts to ensure that the child is safe, and feels physically and emotionally safe, through manipulation of protective and therapeutic equipment or the therapist's physical proximity and actions.
2. Therapist presents sensory opportunities to the child.
   The therapist presents the child with at least two of the following three types of sensory opportunities: tactile, vestibular, and proprioceptive; the therapist's intent is to use sensory input to support the development of self-regulation, sensory awareness, or movement in space. The therapist may provide a variety of sensory opportunities with varying intensities, qualities, speed, and duration to improve perception, challenge postural control or praxis, or to attain an adequate arousal state for sustained engagement.
3. Therapist supports sensory modulation for attaining and maintaining a regulated state.
   The therapist modifies sensory conditions as well as activity challenges and supports to help the child attain and maintain appropriate levels of arousal and alertness, as well as an affective state and activity level that supports engagement in activities.
4. Therapist challenges postural, ocular, oral, or bilateral motor control.
   Challenges are embedded in sensory-motor activities that build bilateral integration, strength, dexterity, speed, and agility in static and dynamic postural control, and in fine motor, gross motor, and oral motor skills.
5. Therapist challenges praxis and organization of behavior.
   Challenges may address the child's ideation (ability to conceptualize and plan novel movement activities), motor planning (ability to plan a novel sequence of movements to engage effectively in a new activity), or organization of behavior in blocks of proximal or distal time and space (e.g., planning activities to do in today's session, or next week).
6. Therapist collaborates with child in activity choice.
   The therapist negotiates activity choices with the child, allowing the child to choose equipment, materials, or specific aspects of an activity. Activity choices and sequences are not determined solely by the therapist. Instead, the therapist provides structuring and support while maximizing the child's active control.
7. Therapist tailors the activity to present a just right challenge.
   The therapist presents or facilitates challenges that are not too difficult or too easy for the child to achieve. This may involve altering an activity so that it is easier (more attainable) or more difficult (requiring more effort). Challenges require some degree of effort and may address motor control, bilateral coordination, sensory modulation, self-regulation, discrimination and perception, or praxis and organization of behavior.
8. Therapist ensures that activities are successful.
   Ensuring success means that the therapist supports the child's experience of success in doing part or all of an activity. For example, this may be done by altering the task at any point in the activity sequence, by coaching the child on alternative ways to do the activity, or by prompting the child to find another strategy.
9. Therapist supports child's intrinsic motivation to play.
   This is done by creating a setting that supports play as a way to fully engage in intervention activities. The therapist builds upon the child's intrinsic motivation and enjoyment of activities through strategies such as communicating nonverbally or verbally that play is encouraged, allowing the child to explore or experiment with actions or objects, or engaging with the child in motor, object, pretend, or social role-play.
10. Therapist establishes a therapeutic alliance with the child.
    The therapist promotes and establishes a connection with the child that conveys they are working together in a mutually enjoyable partnership. Overall, there is a climate of trust, emotional safety, connectedness, and appreciation of the child.

therapeutic strategies while interacting with the child during a therapy session. Process elements reflect both the art and science of therapy. They are very germane to this chapter because they guide the content and tenor of each session. The process elements make the theory accessible and underpin the therapist's reasoning both in- and on-action.

2. *Structural elements,* shown in Table 14-2. Although we show them second here because they are less relevant to this discussion, the structural elements appear first in the ASIFM. They underpin the context of all interventions. They must be present, but because they pertain to the characteristics of the space and the qualification of therapists, they are reasonably static. Once in place, they generally remain in place.

The ASIFM has been used to document or verify fidelity of ASI intervention in both research and practice. It is a useful teaching tool for clarifying the essential elements of ASI intervention and how this intervention can be distinguished from other intervention approaches, such as the examples of compromised fidelity presented at the

TABLE 14-2 Structural Elements of the ASIFM

Therapist Qualifications

1. **Postgraduate training in sensory integration:** Certified in Sensory Integration or Sensory Integration and Praxis Tests (SIPT; Ayres, 1989) through a graduate level university course, with a minimum of 50 education hours in sensory integration theory and practice.
2. **Supervision:** History of mentorship, with an equivalent of 1 hour per month for 1 year, from an advanced-level therapist with at least 5 years of experience providing occupational therapy using ASI intervention.

Safe Environment

1. Mats, cushions, and pillows are available to pad the floor underneath all suspended equipment during intervention.
2. Equipment is adjustable to the child's size.
3. Therapist can monitor equipment easily to ensure safe use.
4. Equipment not being used is stored, anchored, or placed at the side of the room so children cannot fall or trip on it.
5. Frequent monitoring and documentation of equipment and safety occurs (e.g., frayed ropes and bungee cords replaced; loose bolts secured for suspended equipment).

Assessment Report Content

1. Medical, educational, and therapeutic history, as appropriate
2. Developmental history
3. Occupational profile or interview documenting activities the child and family have done, are doing, and want to do
4. Reason for referral
5. Activities child currently seeks and enjoys
6. Results of structured evaluations (i.e., standardized and norm-referenced measures)
7. Results of unstructured evaluations (i.e., clinical observations, parent reports)
8. Sensory modulation, including sensory sensitivities, sensory seeking, and self-regulation
9. Sensory discrimination or perception in tactile, vestibular, and proprioception systems
10. Postural-ocular control (static and dynamic), including ocular, oral, and bilateral motor control
11. Visual, perceptual, or fine motor skills
12. Motor coordination or gross motor skills
13. Praxis: Imitating, constructing, planning, and sequencing one or more activities or interactions
14. Influence of SI on performance and participation
15. Organization skills, such as managing materials, schedules, transitions, and social expectations
16. Interpretation of the relationship of sensory integration and praxis to referring problems
17. Goals and objectives (if applicable) developed in collaboration with significant caregivers
18. Goals (if applicable) focused on presenting concerns based on assessment findings
19. Goals (if applicable) focused on improved skills and abilities to enhance performance

Physical Space for ASI Intervention

1. Adequate space to allow for flow of vigorous physical activity
2. Flexible arrangement of equipment and materials to allow for rapid change of the physical and spatial configuration of intervention environment
3. No fewer than three hooks for hanging suspended equipment, minimal distance between hooks of 2½ to 3 ft. (enough room to allow for full orbit on suspended equipment); additional hooks recommended depending on size of room
4. One or more rotational devices attached to ceiling support to allow 360 degrees of rotation
5. A quiet space (i.e., tent, adjacent room, or partially enclosed area)
6. One or more sets of bungee cords for hanging suspended equipment

Available Equipment

(*Note*: *Facility requirements differ; therefore, similar equipment may be substituted.)*

Does your facility have <u>at least one</u> of each of the following pieces of equipment?

TABLE 14-2 Structural Elements of the ASIFM—cont'd

1. Bouncing equipment (e.g., trampoline)
2. Therapy balls
3. Rubber strips or ropes for pulling
4. Platform swing—square
5. Glider swing—rectangular platform
6. Frog swing (sling swing for prone or sitting)
7. Scooter or ramp
8. Flexion disc swing
9. Bolster swing
10. Tire swing
11. Weighted objects, such as balls or beanbags in a variety of sizes
12. Inner tubes
13. Spandex fabric
14. Crash pillow or pad that can be moved quickly to cushion child's impact when landing or bumping onto hard surfaces
15. Ball pit or ball bag (large bag containing balls in which a child may play)
16. Variety of tactile materials and vibrating toys, such as massagers (e.g., textured fabrics, brushes, carpet square, beans, rice, etc.)
17. Visual targets (e.g., balloons, Velcro darts, hanging objects)
18. Inclines or ramps
19. Climbing equipment (e.g., wooden, plastic, steps, ladders, or stacking tire tubes)
20. Barrels for rolling
21. Props to support engagement in play (e.g., dress up clothes, balls and bats, stuffed animals, dolls, puppets, sports equipment, bikes)
22. Materials for practicing daily living skills (e.g., pencils, pens, and other school supplies; clothing, grooming, and other home-related objects)

Communication with Parents and Teachers

1. Therapists routinely have ongoing interchanges with the child's parents or teacher regarding the course of intervention.
2. Therapists routinely discuss with the parents or teacher the influence of sensory integration and praxis on the child's performance of valued and needed activities.
3. Therapists routinely discuss with the parents or teacher the influence of sensory integration and praxis on the child's participation at home, in school, or in the community.

HERE'S THE EVIDENCE

Research on the ASIFM has revealed that the total fidelity process score has high reliability (*ICC* = .99, Cronbach's *alpha* = .99) and is a valid discriminator of ASI from alternative interventions (Parham et al., 2011). Structural fidelity items have evidence for:

- Content validity as determined by ratings of international experts in ASI (Parham et al., 2011)
- Inter-rater reliability and validity in discriminating settings that provide ASI intervention from those that do not, indicated by analysis of ratings from different groups of international therapists with expertise in ASI (Parham et al., 2011; May-Benson et al., 2014).

beginning of this chapter. The measure was also used to develop the *Clinician's Guide for Implementing Ayres Sensory Integration®* (Schaaf & Mailloux, 2015), a guidebook for training occupational therapists to provide ASI intervention based on the manualized treatment used in Schaaf and colleagues' (2014) randomized trial.

The ASIFM guided and verified the interventions provided in two randomized clinical trials (Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2013) as well as a cohort study of children with autism spectrum disorders (Iwanaga et al., 2013). Future applications of the ASIFM may prove useful in identifying groups of children who are likely to be the best responders to this intervention and in determining outcomes that can be expected from this intervention at different dosages.

HERE'S THE POINT

- The ASIFM gives ready access to ASI to guide the creation of direct interventions and evaluate the fidelity of effectiveness research.
- The ASIFM includes process elements that address both the art and science of intervention and structural elements that address contextual characteristics. Both are equally important to fidelity.
- Data gathered with the ASIFM have shown preliminary evidence for validity and reliability. The ASIFM is beginning to be used to guide research in occupational therapy.

The STEP-SI

■ Lucy J. Miller, PhD, OTR/L, FAOTA

The STEP-SI (Miller, Wilbarger, Stackhouse, & Trunnell, 2002) is another resource for making SI theory accessible for direct intervention. Similar to the ASIFM, the STEP-SI addresses both art and science. In the publications of the STEP-SI (Miller et al., 2002; Stackhouse, Trunnell, & Wilbarger, 1997), the authors refer to it as a clinical reasoning model for intervention with children with sensory modulation disorder. But, of course, promoting self-regulation is an important principle for all children. See also Miller and colleagues (2002) for additional detail.

The STEP-SI model was developed originally for a randomized controlled trial evaluating the effectiveness of sensory integrative therapy; it is expressed in a treatment manual and a fidelity to treatment scale. In creating the STEP-SI, expert occupational therapists extracted what they considered to be the essential elements of the therapeutic process from videotaped therapy sessions. The acronym, *STEP-SI,* serves as a prompt for remembering the active components (dimensions) of treatment: Sensation, Task, Environment, Predictability, Self-monitoring, and Interaction (Miller et al., 2002). The therapist manipulates each of the STEP-SI dimensions to support or challenge a child's developmental capacities, serving to develop capacities or skills in identified problem areas. The appropriateness of the child's adaptive response becomes a monitor that guides modification of intervention.

The **components** or dimensions of the STEP-SI intervention model comprise these variables:

S **Sensation:** *Sensory modalities:* tactile, vestibular, proprioception, audition, vision, taste, olfaction, oral input, and respiration. *Qualities of sensation:* duration, intensity, frequency, complexity, and rhythmicity.

T **Task:** Structure, complexity, demand for skill, demand for sustained attention, level of engagement, fun, motivation, and purposefulness (based on standard task analysis)

E **Environment:** Organization, complexity, perceived comfort and safety, and possibilities for engagement, exploration, expansion, and self-challenge

P **Predictability:** Novelty, expectation, structure, routine, transitions, and congruency; level of control by child or practitioner and control of events and routines

S **Self-Monitoring:** Moving children from dependence on external cues and supports to a self-directed and internally organized ability to modify their own behavior and manage challenges

I **Interactions:** Interpersonal interaction style, including responses to supportive, nurturing styles vs. more challenging, authoritative styles; locus of control (practitioner guided vs. child directed); and demands or expectations for engagement (i.e., passive awareness to active collaboration)

General Principles of STEP-SI

The STEP-SI framework comprises a series of implementation segments (aims) and questions that guide intervention and assist therapists to make effective decisions that maintain the flow of a session. The method assists practitioners to design interventions to impact a child's ability to self-regulate. This information, combined with standardized assessment data, helps establish levels of adaptation in each of the STEP-SI dimensions.

In the context of a session, a therapist uses the implementation segments (aims) and questions to think about each STEP-SI dimension and how the child is responding. Which will be held constant and which subtly changed? Once a practitioner understands the child better by testing what challenges and supports the child, the practitioner can balance multiple challenges with multiple supports. The therapist's goal within each treatment session is to keep the child moving forward at a "just right" rate of challenge and achieving a balance between child-directed activities and challenges the child avoids. Therapists must support the child right to the edge of his or her ability to adapt, but not beyond. The push toward the edge of adaptive ability allows children to expand their adaptive capacities.

The general principles of the STEP-SI model are also used to plan for future sessions. Clinicians reflect after each session regarding the appropriateness of activities, tasks, and the environment. The information gleaned is shared with the family and used to make suggestions for the child at home and in the community.

Intervention Segments (Aims)

In each session and afterward, the therapist seeks to:

1. *Understand the child's arousal state and adaptive capacity.* The therapist determines the child's state of arousal and ability to attain appropriate behavioral organization and then seeks to help the child maintain a level of arousal within an optimal range. The therapist must be aware of the child's responses to challenges in the day or week and compare the conditions that result in organized versus disorganized responses.
2. *Examine how each STEP-SI dimension affects the child's state of arousal and ability to attain or maintain appropriate behavioral organization.* The therapist determines which aspects of each STEP-SI dimension enable the child to have the best adaptive response and which challenge the child's adaptation.
3. *Prioritize the utilization of each STEP-SI dimension to support or challenge children.* The therapist manipulates each dimension of the model one at a time to maximize appropriate levels of adaptation and occupational performance.
4. *Monitor and re-adjust each STEP-SI dimension based on ongoing assessment of adaptive responses.* Once optimum adaptive performance is achieved, the therapist introduces another "just right challenge" by altering some aspect of the situation. This constant "upping the ante" while scaffolding the child to maintain organization within each new "challenge state" is the key to making the adaptive changes suggested by Ayres (1972).

The guiding questions listed here assist the therapist in implementing intervention and families to understand and interact most effectively with their child.

1. How does *sensation* serve to challenge or support the child? What, if any, sensation does the child crave? Avoid? Seem unaware of? How do these craving, avoiding, or unaware behaviors enhance or diminish the child's behavioral organization and functional performance?
2. What kinds of *tasks* and qualities of tasks serve to challenge or support the child? What qualities of tasks, task structures, or task complexity enhance or support the child's behavioral organization or functional performance?
3. What kinds of *environments* and qualities of the environment serve to challenge or support the child? What qualities of the environment or level of environmental stimulation, enrichment, structure, organization, and perceived safety enhance or support the child's behavioral organization or functional performance?
4. How does *predictability* serve to challenge or support the child? What qualities of predictability, including child-controlled actions, enhance or support the child's behavioral organization or functional performance?
5. How does the child's ability to *self-monitor* serve to support him or her in challenging situations? Can the child recognize which strategies and activities help his or her own internal state or his or her ability to complete activities or have appropriate adaptive responses?
6. How do *interactions* challenge or support the child? What qualities of interactions (e.g., active scaffolding) enhance or support the child's behavioral organization or functional performance?

Table 14-3 contains options for using the STEP-SI dimensions to support a particular child in a challenging activity in an upcoming intervention session. Before beginning the intervention session, the therapist has nearby all the

TABLE 14-3 Example of the Use of STEP-SI Dimensions to Support a Challenging Sensory Activity

TASK	ENVIRONMENT	PREDICTABILITY	SELF-MONITORING	INTERACTION
Use structured activities during swinging on bolster or a motor challenge (e.g., shooting arrows at a target during swinging to practice for battle).	Use low levels of background noise and light. Be structured and neat. Provide only a few interesting options for activities (e.g., clear the battle field so the great warrior can focus).	Set up a routine for beginning and ending the session with taking shoes off and putting them back on. Start with a familiar activity from the previous session. Give the child control through choices (e.g., warriors must have a ritual they follow).	Provide a hideout space. Give the child verbal feedback regarding when he or she is able to stay calm and when he or she is getting overwhelmed (e.g., use the hideout when the battle "gets too rough").	Use a nurturing, low demand, calm and steady voice (e.g., you are the battle coach and you don't want the other side to hear you).

TABLE 14-4 Reflective Questions for Therapists: Following a Direct Intervention Session

- How did the child respond? What was the adaptive response? Did the child or therapist find the just right challenge? Was any of the session child-directed? Was the child purposeful and intrinsically motivated? What worked to provide support and appropriate challenges?
- What questions do you have for the next intervention session?

sensory equipment and STEP-SI tools that he or she will use in the session. Table 14-4 contains reflective questions the therapist might ask following a direct intervention session.

Establishing Specific Goals and Priorities for STEP-SI Intervention

The primary focus of occupational therapy is to assist children and families to improve their occupational roles and functional performance. Therapists may assist a child by remediating specific sensory or motor dysfunction but always in the context of occupations and always focusing on the family's priorities (Cohn, 2001a, 2001b). Although beyond the scope of this chapter, Bialer and Miller (2011) emphasized that intervention guided by the STEP-SI model is situated in goals to address occupational performance, performance components, self-regulation, social participation, and self-esteem.

HERE'S THE POINT

- STEP-SI is a clinical reasoning guide that assists therapists to conduct direct intervention sessions in the most effective and efficient manner for each individual child.
- STEP-SI directs therapists to consider six dimensions that affect a child's regulation and performance: sensation, task, environment, predictability, self-monitoring, and interactions.
- Therapists can use the STEP-SI to reason "in-the-moment" and reflect on a session following its conclusion.

Models to Help Families Thrive

Not only therapists seek tools that give them ready access to theory. Families also seek simple ways to draw from SI theory in order to interact effectively with their children in the context of problematic everyday activities and routines. A creative and flexible problem-solving approach can be even more useful than set techniques; the latter begin to feel similar to the cookbook that we try to avoid when applying ASI.

A SECRET

■ Lucy J. Miller, PhD, OTR/L, FAOTA

So many parents expressed that occupational therapists seem to have "a secret" for solving everyday problems of children with sensory processing (i.e., sensory integrative) dysfunction that Bialer and Miller (2011) used the acronym A SECRET to define a problem-solving approach for parents and children. A SECRET is predicated on the notion that families and children can manipulate any of seven elements to solve problems wherever and whenever they arise—at home, in school, or in the larger community. The acronym provides an easy way to remember and use problem-solving fundamentals in everyday life. The seven elements of the acronym are as follows:

A Attention
S Sensation
E Emotion regulation
C Culture
R Relationships
E Environment
T Tasks

The first three elements—attention, sensation, and emotion regulation—are internal characteristics that influence a child (i.e., internal dimensions). The last four elements—culture, relationships, environment, and tasks—are the contextual elements that influence a child from the outside (i.e., external dimensions).

In any problematic situation, a parent or child who knows A SECRET can first define the child's problem area (e.g., will not sit through dinner; cannot play successfully with a peer). Then the therapist and parent can work together to explore the elements of A SECRET to plan for what can be done before or during a difficult episode outside of therapy to assist the child in regaining regulation:

A: Is there a way I can draw my child's (or my) *attention* away from this problem?
S: Is there a *sensation* that is alarming my child (or me) right now? If so, what is it, and can it be modified? Can I use another sensation to override the alarming one?
E: What *emotion* is my child (or am I) experiencing, and what techniques do I know to support emotion regulation for the child (or myself) that work when the child feels (or I feel) this way?
C: What part of the *culture* (context) can be changed to avoid situations such as this in the future? For example, upsets in the grocery store: Could I do this activity without my child? Could we do something to change the activity or context to make it easier or more pleasant for my child (or for me) (e.g., couple the activity with a task such as matching coupons to items selected at the store)?
R: Is there something in a *relationship* with me or someone else right now that's causing my child (or me) to act this way? What can I do about it? Or how can I use the power of my relationship to lessen the situation?
E: What in the *environment* is setting off my child (or me)? How can I modify it? Or is there something in the environment I can use to help my child (or myself)?
T: What is troubling my child (or me) about the *task* at hand? How can the task be modified so that it is not so problematic for my child (or me)? Is there a task that I can use to provide a calming influence? For example, the problem area is that the child is unable to maintain regulation during a worship service. Can I discover what tasks will keep the child engaged (e.g., a color-by-number or dot-to-dot activity)?

Using the problem-solving approach defined by A SECRET, families and children can incorporate workable strategies into daily routines—getting up in the morning, eating, going to school and work, coming home, doing homework, and ending the day. For example, a child at risk for melting down in the supermarket might have a **T**ask that helps him get through the experience more easily: "Can you cross off each item on the shopping list when I find it?" Or, that same parent might alter her **R**elationship with the child in the moment—if he's little, picking the child up and carrying him through the store or introducing an interactive game: "Let's see who can find the most yellow boxes in this row." Or, the parent might provide **S**ensory input with a hard, calming hug or a thick drink the child could suck through a straw while shopping. More details for implementing A SECRET are available in Bialer and Miller (2011).

HERE'S THE POINT

- A SECRET is an example of a reasoning tool that extends SI theory to families and children for use in everyday activities and routines.
- A SECRET describes both internal influences (i.e., attention, sensation, and emotion regulation) and contextual influences (i.e., culture, relationships, environment, and tasks).

- A SECRET involves guiding questions that help a parent or child develop a strategy to address problematic situations in context.

Summary and Conclusions

SI is arguably the most complex of the occupational therapy practice theories. The four resources we presented in this chapter can guide therapists' clinical reasoning and parents' problem-solving in problematic situations by providing them with ready access to SI theory.

As useful as it can be for evaluation and intervention, SI theory is only one practice theory within the broad field of occupational therapy. For occupational therapy to be optimally effective, most children and families will require intervention drawn from more than one practice theory. Thus, therapists using SI theory to intervene with any particular child and family must see how it fits into their broader professional role.

Further, occupational therapy is only one service that many families and children receive. Therapists also must be clear about the place of occupational therapy, as a whole, within the health or educational services that a child and family require. Many therapists have created comprehensive programs that involve occupational therapy and SI but that go beyond them. The STAR Treatment Model is one of those. We include specific information about the STAR model in Appendix A.

Where Can I Find More?

Bialer, D. S., & Miller, L. J. (2011). *No longer A SECRET: Unique common sense strategies for children with sensory or motor challenges.* Phoenix, AZ: Future Horizons/Sensory World.

This book, written in simple language, provides access to several strategies families can use in the context of everyday routines to increase their sustainability.

Miller, L. J., Wilbarger, J., Stackhouse, T., & Trunnell, S. (2002). Use of clinical reasoning in occupational therapy: The STEP-SI model of intervention of sensory modulation dysfunction. In A. C. Bundy & S. J. Lane, *Sensory integration: Theory and practice* (2nd ed., pp. 435–452). Philadelphia, PA: F. A. Davis.

The full STEP-SI model is published as an appendix to the second edition of this text. The authors describe use of the model in assessment, intervention, and to develop home and community programs. They provide an in-depth case study to illustrate use of the STEP-SI.

Parham, L. D., Roley, S. S., May-Benson, T., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on Ayres Sensory Integration. *American Journal of Occupational Therapy, 65,* 133–142. doi:10.5014/ajot.2011.000745

Parham and colleagues describe the process for developing the ASIFM.

References

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests (SIPT)*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972). *Sensory integration and learning disabilities*. Los Angeles, CA: Western Psychological Services.

Bialer, D. S., & Miller, L. J. (2011). *No longer A SECRET: Unique common sense strategies for children with sensory or motor challenges*. Phoenix, AZ: Future Horizons/Sensory World.

Cohn, E. S. (2001a). From waiting to relating: Parents' experiences in the waiting room of an occupational therapy clinic. *American Journal of Occupational Therapy, 55*(2), 167–174.

Cohn, E. S. (2001b). Parent perspectives of occupational therapy using a sensory integration approach. *American Journal of Occupational Therapy, 55*(3), 285–294. doi:10.5014/ajot.55.3.285

Iwanaga, R., Honda, S., Nakane, H., Tanaka, K., Toeda, H., & Tanaka, G. (2013). Pilot study: Efficacy of sensory integration therapy for Japanese children with high-functioning autism spectrum disorder. *Occupational Therapy International, 21,* 4–11. doi:10.1002/oti.1357

Kazdin, A. E. (1994). A model for developing effective treatments: Progression and interplay of theory, research, and practice. *Journal of Clinical Child Psychology, 26,* 114–129.

May-Benson, T., Roley, S. S., Mailloux, Z., Parham, L. D., Koomar, J., Schaaf, R. C., . . . Cohn, E. (2014). Interrater reliability and discriminative validity of the structural elements of the Ayres Sensory Integration® Fidelity Measure.© *American Journal of Occupational Therapy, 68,* 506–513. doi:10.5014/ajot.2014.010652

Miller, L. J., Wilbarger, J., Stackhouse, T., & Trunnell, S. (2002). Use of clinical reasoning in occupational therapy: The STEP-SI Model of Intervention of Sensory Modulation Dysfunction. In A. C. Bundy & S. J. Lane, *Sensory integration: Theory and practice* (2nd ed., pp. 435–452). Philadelphia, PA: F. A. Davis.

Moncher, F. J., & Prinz, R. J. (1991). Treatment fidelity in outcome studies. *Clinical Psychology Review, 11,* 247–266.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J., Miller, L., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61,* 216–227.

Parham, L. D., Roley, S. S., May-Benson, T., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for Research on Ayres Sensory Integration. *American Journal of Occupational Therapy, 65,* 133–142. doi:10.5014/ajot.2011.000745

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy, 65*(1), 76–85.

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kelly, D. (2014). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders, 44,* 1493–1506. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration®: Promoting participation for children with autism*. Bethesda, MD: AOTA Press.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

Stackhouse, T. M., Trunnell, S. L., & Wilbarger, J. L. (1997). *Treating sensory modulation disorders: The STEP-SI: A tool for effective clinical reasoning*. Denver, CO: The Children's Hospital.

Wolery, M. (2011). Intervention research: The importance of fidelity measurement. *Topics in Early Childhood Special Education, 31,* 155–157.

PART

V

Complementing and Extending Theory and Application

CHAPTER

15

Advances in Sensory Integration Research: Clinically Based Research

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Research is formalized curiosity. It is poking and prying with a purpose.

—Zora Neale Hurston

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Identify and compare features of report-based and performance-based measures used in clinical research for evaluation of sensory integrative disorders.
- ✔ Analyze the state of current intervention research for sensory integrative disorder and identify tools for enhancing rigor in intervention research.
- ✔ Identify clinical outcomes that can be expected to change following sensory integrative interventions.
- ✔ Examine genetic, prenatal, and perinatal factors influencing the development of sensory integrative disorders and how these issues can influence function and participation.

Introduction

Sensory integration (SI), as described by Ayres, refers to a theory, a group of clinical disorders, and a treatment approach (Ayres, 1972a). Considerable research has been conducted to support the identification of clinical disorders, and to examine treatment efficacy and effectiveness. Ayres relied on early neuroscience research (1960–1988) to gain insights into the characteristics of sensory integrative disorders, explain relationships among neurological processes and overt behaviors, and to develop an intervention approach (Ayres, 1972a). SI theory aims to increase our understanding of underlying mechanisms that result in behavioral, emotional, motor, and social difficulties as well as problems in learning. SI theory also highlights underlying neuroscience principles that guide the clinical practice and provides a rationale for the way intervention is administered.

Although occupational therapists have been using an SI frame of reference for decades, controversy still exists regarding the effectiveness of this approach both within and outside of the profession. Somewhat earlier research found that evidence was promising but inconclusive (Case-Smith, Weaver, & Fristad, 2015; May-Benson & Koomar, 2010). In response to the American Academy of Pediatrics (AAP) statement in 2012, Miller and colleagues state, "We agree with the AAP committee's conclusion that caution is warranted in labeling the disorder; treating the symptoms is much more important than the diagnostic category into which the label falls" (Miller, 2012, para. 2). In a systematic review, Schoen et al. (2019) concluded that ASI is effective for children with autism. In fact, the time is ripe for producing the scientific data needed to establish sensory processing disorder (SPD) as a unique diagnosis, often comorbid in other clinical conditions in children and adults, as well as evidence of the effectiveness of the intervention.

As was noted in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) relative to SI theory, terminology in the research lacks consistency. Although Ayres used "SI disorders," Miller and others chose to use the phrase "sensory processing disorders" (SPD) to describe the same phenomena. Further, the differentiation between the collection of disorders identified in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited) and the specific category of sensory modulation disorders (SMD) has also become blurred. In this chapter, we will use *sensory integrative disorders* as the broad term; research that looked at the full array of sensory integrative concerns will be covered here. *SMD* will be used when discussing research relative to modulatory functions of the central nervous system (CNS). Grouped under SMD we will present research that has focused on sensory over-responsivity (SOR). This will often differ from terminology used in individual articles.

Purpose and Scope

The focus of this chapter is to unpeel the evidence supporting SI identification and the definition of SI disorders, links between neuroscience and behavior, and sensory integrative treatment. We summarize recent advances in applied research on sensory processing, modulation, and integration, focusing on disorders of sensory modulation. We covered the vast body of research on dyspraxia, including research on related diagnoses such as developmental coordination disorder and links with autism spectrum disorder, in Chapter 5 (Praxis and Dyspraxia) and will not repeat that here. However, when appropriate, we address aspects of motor function and dysfunction. A subsequent chapter will address basic science research related to sensory processing and SI.

Identifying and Defining the Disorders; Research Related to Assessment

An important prerequisite for acceptance and definition of a disorder is a gold standard tool that describes its characteristics. Because sensory integrative disorders are not accepted by the *Diagnostic and Statistical Manual* or *International Classification of Disorders,* it is not yet considered a "real" diagnosis or stand-alone condition. The occupational therapy literature contains many standardized measures, most of which rely on informant report (parent, teacher, caregiver); these will provide information "by proxy" and should be interpreted carefully. There is a growing awareness of the need for standardized *performance measures* of sensory modulation and SI to supplement these proxy report measures in the evaluation and identification of sensory integrative disorders.

Rating Scales: Standardized Report Measures

The most widely used report measures are the family of assessments known, collectively, as the Sensory Profile (SP), developed by Dunn (1999, 2006, 2014) and Brown and Dunn (2002). Recently revised, the Child SP™2, the School Companion SP™2, and the Short SP™2 are applicable to children from 3 to 10 years of age (Dunn, 2014). Also included in this revision are the Toddler SP™2 and the Infant SP™2, for children 7 to 35 months of age and birth to 6 months of age, respectively. The Adolescent and Adult SP is applicable for children 11 years of age and older (Brown & Dunn, 2002). The SPs examine sensory processing patterns in individuals who are at-risk or have specific disabilities related to sensory processing issues. Responses are based on self- or caretaker reports. Resulting profiles from the measures highlight the effects of impaired sensory processing on functional performance in the daily life of an individual. The original scales were standardized nationwide (samples ranging from 500 to 1,200); the revised tools were standardized on samples ranging from $n = 68$ (Infant) to $n = 697$ (Child SP2, Short SP2, and School Companion SP2). Information on reliability of the SP™2 and the Adolescent and

TABLE 15-1 Reliability for the Sensory Profile 2 Tools

	INTERNAL CONSISTENCY	TEST/RETEST RELIABILITY	INTER-RATER RELIABILITY
Infant	0.75	0.86	
Toddler	0.57–0.8	0.83–0.92	
Child	0.60–0.90	0.87–0.97	0.49–0.89
School	0.81–0.92	0.66–0.93	0.53–0.90
Child/Short	0.79–0.93	0.93–0.97	
Adolescent/Adult	0.64–0.78		

Note: Adapted from Pearson. (2005). Adolescent/Adult Sensory Profile technical summary. Downloaded 7-31-2015 from http://www.pearsonclinical.com/therapy/products/100000434/adolescentadult-sensory-profile.html#tab-resources; and Pearson (2014). Sensory Profile 2 technical summary. Downloaded 7-31-2014 from http://www.pearsonclinical.com/therapy/products/100000822/sensory-profile-2.html#tab-resources.

Adult SP can be found in Table 15-1. Discriminate and convergent validity have been examined by the authors and is available in the manuals for each tool (Brown & Dunn, 2002; Dunn, 2014).

The Sensory Processing Measure™ (SPM: Parham, Ecker, Kuhaneck, Henry, & Glennon [2010]) is modeled on diagnostic subtypes in the *Diagnostic Manual for Infancy and Early Childhood: Mental Health, Developmental, Regulatory-Sensory Processing and Language Disorders and Learning Challenges* (ICDL-DMIC Work Groups, 2005) and the DC: 0-3 (Zero to Three, 2005). Not unlike the SP, the SPM has versions for children 5 to 12 years of age and for preschool children from 2 to 5 years of age (SPM Preschool). The SPM screens for SOR, sensory under-responsivity (SUR), and sensory seeking, as well as posture, praxis, and discrimination challenges specifically with both home (caretaker) and school (teacher) scales. The SPM was standardized on 1,051 children in grades K through 6 and the SPM-P on 893 children from 2 to 5 years of age. Both have excellent reliability (scale internal consistencies range from 0.75 to 0.95; 2-week test-retest correlations range from 0.94 to 0.98) and validity (evidence for validity includes factor analytic studies, correlational results, and clinical discrimination studies). False positive rates are 15% using a cutoff *T*-score of 60 (lower bound of "Some Problems") and 2% using a cutoff *T*-score of 70 (lower bound of "Definite Dysfunction"). Table 15-2 provides a comparison of features offered by the SP2 and the SPM.

In order to improve the diagnosis of SMD in adults, a newer scale, the Sensory Responsiveness Questionnaire (SRQ; Bar-Shalita, Vatine, & Parush, 2008), was developed as a comprehensive measure to assess SMD in adults 20 to 60 years. This self-report questionnaire contains 58 items representing all sensory modalities. The tool uses a five-point Likert scale on which individuals respond to two previously understudied components of SPD: "intensity of affective response to sensory stimuli" and "frequency of occurrence of affective responses." The questionnaire had high test-retest reliability ($r = 0.71$ to 0.74), moderate criterion validity ($r = 0.34$ to 0.61), and strong significant construct validity.

In addition to scales specifically designed for individuals with SI and processing disorders, there have been a growing number of non-standardized parent and self-report measures designed to assess sensory modulation dysfunction in other clinical populations. The goals are to promote improved differential diagnosis and to inform development of future report measures. Most notable are three caregiver or parent report measures: The Sensory Experiences Questionnaire (Baranek, David, Poe, Stone, & Watson, 2006); the Sensory Sensitivity Questionnaire (Minshew & Hobson, 2008; Talay-Ongan & Wood, 2000); and the Diagnostic Interview for Social and Communication Disorders (DISCO; Leekam, Libby, Wing, Gould, & Taylor, 2002). The Sensory Experiences Questionnaire is a brief questionnaire for caregivers designed to reflect behavioral responses to typical daily sensory experiences in infants, toddlers, and young children (ages 5 months to 6 years of age). Its primary purpose is to discriminate symptoms of SOR from SUR. The questionnaire has strong internal reliability consistency ($\alpha = 0.8$) and discriminates between children with autism,

TABLE 15-2 Comparison of Sensory Profile (SP) and Sensory Processing Measure (SPM)

	FORMS	PUBLICATION YEAR	AGES	SCORES
SP2; Adolescent/ Adult SP	• Infant SP2 • Toddler SP2 • Child SP2 • School Companion SP2 • Short SP2 (SSP2) • Adolescent and Adult SP (AASP)	2014 2002	Infant SP2: birth–6 mo Toddler SP2: 7–35 mo SP2, School Companion SP2, SSP2: ages 3–10 yrs AASP: 11 yrs+	Sensory section • Auditory • Visual • Touch • Movement • Body position • Oral Behavioral section • Conduct • Social-emotional • Attention Sensory quadrant • Registration • Seeking • Sensitivity • Avoiding School Companion SP2, School Factors • Supports • Awareness • Tolerance • Availability
SPM	SPM Preschool SPM Home, Main Classroom, School Environments	2010 2007	2–5 years 5–12 years	Home and Main Classroom, 8 scores: • Social participation • Vision • Hearing • Touch • Body awareness (proprioception) • Balance and motion (vestibular function) • Planning and ideas (praxis) • Total sensory systems

developmental delays, and typical controls. The Sensory Sensitivity Questionnaire is a self-report measure that consists of 13 items related to SOR. Significant differences are reported between the autism and control groups for tactile sensitivities as well as sensitivity to heat, cold, and pain. In addition, there were important individual differences within the autism sample with some individuals showing substantial sensory sensitivities and others scoring within a typical range. The DISCO is a semi-structured parent interview designed to recognize and identify the impairments and core features of autism spectrum disorders (Wing, Leekam, Libby, Gould, & Larcombe, 2002). It includes 25 sensory items that are similar to items on the Sensory Profile (Kientz & Dunn, 1997). A child's response to sensory stimuli is rated as "marked abnormality," "minor abnormality," or "no problem" (Leekam, Libby, Wing, & Gould, 2007).

Standardized Performance Measures

The Sensory Integration and Praxis Test (SIPT; Ayres, 1989) scale has been widely used by occupational therapists to evaluate SPD based on Ayres' (1972a) constructs. Standardized nationwide on 1,997 children, the SIPT includes 17 subtests, each having separate reported reliability and validity. More information on the

SIPT can be found in Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests). Content, construct, and discriminative validity have been examined for the SIPT (Carrasco, 1991; Lai, Fisher, Magalhaes, & Bundy, 1996; Royeen, Koomar, Cromack, & Fortune, 1991; Royeen & Mu, 2003; Walker & Burris, 1991) and include the many factor analyses conducted by Ayres (1969, 1972b, 1977, 1989) and others (Mailloux et al., 2011; Mulligan, 1998). Table 11-3 in Chapter 11 (Interpreting and Explaining Evaluation Data) provides a summary of the outcomes of factor analyses. The largest of these, using more than 10,000 SIPT protocols, used structural equation modeling as a means of confirming existing factor models and exploring models that might produce a better fit for existing data (Mulligan, 1998). This work confirmed that sensory integrative disorders are multidimensional. Mulligan found that the SIPT defines one higher order model, which she termed *practic dysfunction,* as well as four first order factors (visual perceptual deficit, bilateral integration and sequencing deficit, dyspraxia, and somatosensory deficit). Although the SIPT does not provide a direct measure of SMD, clinical observations of the child's performance on specific subtests (Fig. 15-1) provide important information regarding the presence of SOR, SUR, or sensory craving symptoms.

Mailloux and colleagues (2011) combined information from the SIPT, items chosen from the SPM to reflect tactile defensiveness, and behavior ratings of attention in their factor analysis. They also found that a four-factor solution was the best fit for the data:

FIGURE 15-1 The SIPT provides a performance-based measure of sensory discrimination and praxis abilities for children from 4 years of age to 8 years, 11 months of age.

- Visuodyspraxia and somatodyspraxia, verifying previous work, and substantiating disorders of praxis
- Vestibular and proprioceptive bilateral integration and sequencing (vestibular and proprioceptive BIS), substantiating the hypothesized relationship between vestibular under-responsivity and other measures of vestibular and bilateral function
- Tactile and visual discrimination, similar to a sensory factor found by both Ayres and Mulligan
- Tactile defensiveness and attention problems, substantiating this proposed link

Additional Measures of Performance and Parent or Self-Report

A review of the occupational therapy literature demonstrates some early attempts to develop a performance measure specific to SMD. One involved the development of an observation scale that categorized the clinician's observations of responses to tactile stimulation (Bauer, 1977), another was a scale piloted on children with severe cognitive deficits (Kinnealey, 1973), and a third was developed to measure tactile over-responsivity in children with developmental disabilities (Baranek, 1998).

There has been a growing realization of the importance of performance measures in accurately assessing sensory integrative disorders in other clinical populations. Most notably is the work of Baranek and colleagues (2007) who have been developing the Sensory Processing Assessment for children with autism and developmental delays. This play-based assessment is designed to characterize sensory processing patterns of hyper- and hypo-responsiveness in the auditory, visual, and tactile domains for children with ASD, from 6 months of age to 6 years of age, based on whether the stimuli are social or nonsocial. None of these scales is readily available for use by clinicians, and limited normative data has been reported.

Miller and colleagues have been working on a standardized method to assess SMD through the development of the Sensory Processing 3 Dimensions Scale, previously known as the Sensory Processing Scale (SP3D; Schoen, Miller, & Green, 2008; Schoen, Miller, & Sullivan, 2014). In development since 2004, the

FIGURE 15-2 The SP3D scales are currently in development and will include both report and performance-based measures of sensory modulation.

SP3D scale measures sensory processing in all sensory domains (vision, audition, touch, olfaction, taste, proprioception, and vestibular; Fig. 15-2). The scale includes both a parent or self-report inventory (Schoen, Miller, & Sullivan, 2016) and a performance assessment where specific standard items are administered by a trained examiner. Psychometrics of the instrument were established in three stages of study: (1) instrument development; (2) reliability and validity of the research edition; and (3) cross-validation of findings on the research edition with a second sample. Analyses of the SOR portion of the SP3D revealed moderate to high internal consistency of reliability for the domains ($\alpha = 0.60$ to 0.89) and the total test ($\alpha = 0.92$). The reliability estimates for the SOR Inventory (parent report companion) ranged from $\alpha = 0.65$ to 0.88 for the domains and 0.97 for the total test. Both the total test and domain scores discriminated groups (over-responsive vs. typically developing) at a meaningful and statistically significant level (significance by domain ranged from $p <$ .05 to $p <$ .001) (Schoen et al., 2008). Preliminary evidence was found for construct validity through factor analyses and by the significant relations between the assessment subtest and its corresponding inventory subtests. Evidence that both the performance measure and the caregiver report measure are needed is highlighted by their moderate correlation, near 0.40, suggesting that different information is provided by the respondent versus direct observation scales.

Recently the SP3D was expanded to include SUR and sensory craving (Schoen et al., 2014, 2016). Both the parent or self-report measure and a performance assessment have been field tested. Following item reduction, reliability and validity at the level of sensory domains and total test was established. Factor analysis confirmed the theoretical structure of sensory modulation subtypes. Similarly, the new assessment appears to be a reliable and valid measure of sensory modulation (scale reliability, $\alpha > 0.90$; discrimination between groups' effect sizes > 1.00) (Schoen et al., 2014). The preliminary psychometric integrity of the scale and its clinical utility provide an important contribution toward development of a "gold-standard" to evaluate SMD. This scale has the potential to aid in differential diagnosis of sensory modulation issues. Mailloux and colleagues (Mailloux, Parham, Roley, Ruzzano, & Schaaf, 2018) are standardizing, worldwide, a new performance-based assessment for children 3 to 12 years. The Evaluation of Ayres Sensory Integration (EASI) measures sensory perception, sensory responsiveness and motor abilities. Preliminary investigation yielded evidence for good construct validity and internal reliability.

HERE'S THE POINT

- SMDs have been most commonly assessed using caregiver report tools such as the Sensory Profile and the SPM.
- Performance-based assessments, such as the SIPT, have been used clinically and in research; more performance-based measures are currently in development.
- Factor analyses conducted during the past several years largely support each other and confirm the existence of hypothesized patterns of dysfunction.

Research Related to Intervention

To be consistent with the American Occupational Therapy Association's Centennial Vision, interventions we employ must be science-driven and evidence-based. As stated in the 2011 research agenda (AOTA, AOTF, 2011), interventions must be defined, described, and tested. This has been an area of concern, particularly for research related to SI. There is a long history of misinterpretation, with researchers reporting on sensory-based interventions that do not adhere to the techniques and principles of SI as defined by

Ayres and subsequent researchers. Therefore, evaluating the literature on the effectiveness of SI means knowing that it is not the same as using a weighted vest (Cox, Gast, Luscre, & Ayres, 2009; Fertel-Daly, Bedell, & Hinojosa, 2001; Hodgetts, Magill-Evans, & Misiaszek, 2011a, 2011b; Kane, Luiselli, Dearorn, & Young, 2004; Leew, Stein, & Gibbard, 2010; Reichow, Barton, Sewell, Good, & Wolery, 2010), applying a brushing protocol (Davis, Durand, & Chan, 2011), swinging, jumping, bouncing on a ball, being wrapped in a blanket (Devlin, Healy, Leader, & Hughes, 2009; Van Rie & Heflin, 2009), sitting on a ball chair (Bagatell, Mirigliani, Patterson, Reyes, & Test, 2010; Schilling & Schwartz, 2004), or a sensory diet (Fazlioglu & Baran, 2008). Readers are reminded to refer to Chapter 12 (The Art of Therapy) and Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), respectively, for thorough definitions and descriptions of the sensory integrative approach.

The gold standard for outcome studies is **randomized controlled trials** (Bury & Mead, 1998) comparing the targeted intervention with an alternative treatment, an active placebo, or a passive placebo or no treatment condition (e.g., a wait-list). Criteria for rigorous randomized trials are well established (Boruch, 1997; Friedman, Furberg, & DeMets, 2015) and mandate inclusion of four primary criteria: (1) an objectively defined sample that is homogeneous with regard to the impairment studied (Bulpitt, 1983); (2) a **"manualized intervention"** where treatment is detailed in a manual that others can obtain to replicate the procedures (Boruch, 1997) with a method to monitor adherence to the specified delivery of treatment (Ottenbacher, 1991); (3) outcomes that are meaningful, appropriate, and sensitive to hypothesized changes (Fuhrer, 1997); and (4) methodology that is rigorous (e.g., [a] random allocation to experimental and control treatment groups, [b] blinded outcome evaluators, and [c] adequate power to evaluate the significance of effects [Jadad, 1998]).

Previous Studies of Occupational Therapy with a Sensory-Based Approach

Before 2007, there was little consensus in the literature as to the effectiveness of the SI approach. In spite of relatively universal agreement about the lack of well-controlled outcome studies, significant controversy existed regarding the interpretation of the findings of published articles from the field regarding the effectiveness of occupational therapy using a sensory integrative approach. Relevant publications included two meta-analyses (Ottenbacher, 1982b; Vargas & Camilli, 1999) and four research syntheses (Arendt, MacLean, & Baumeister, 1988; Hoehn & Baumeister, 1994; Polatajko, Kaplan, & Wilson, 1992; Schaffer, 1984). One meta-analysis suggested that the intervention approach did have a positive effect, but the article is over 30 years old (Ottenbacher, 1982a). The four review articles concluded that previous studies were *not* rigorous enough to make valid conclusions; at the same time, they concluded that occupational therapy was not effective. The other meta-analysis suggested that SI was more effective than no intervention in earlier studies, but it had no positive treatment effect in later studies; SI was found to be as effective as alternative interventions (Vargas & Camilli, 1999), but significant methodological flaws in the SI articles were identified in this paper, including: (1) studies had extremely small sample sizes (median sample size = 4.5 for 13 studies), (2) samples were heterogeneous regarding diagnostic groups, (3) such general descriptions of treatment were provided that replication was impossible, and (4) studies had such poor power that an effect was unlikely to be detected if present (type 2 error). These reviews found that none of the research studies published previously that evaluated treatment outcomes met all four rigorous criteria for a randomized trial (and often did not meet even one criterion) (Miller, 2003). Thus, as of 2003, the only accurate conclusion that could be proffered was that no rigorous evidence exists supporting or denying the effectiveness of this treatment.

Since these reviews were conducted, there have been 12 additional studies, eight of which were included in the systematic review described next.

In 2010, a **systematic review** of evidence for the effectiveness of SI was published in a special issue of the *American Journal of Occupational Therapy* (May-Benson & Koomar, 2010). This review paper included 27 research studies conducted from 1972 through 2007. In addition, specific inclusion criteria were used for the selection of qualifying studies such as (1) authors had reported the intervention was based on an SI approach, (2) participants identified as having deficits in sensory processing and integration, and (3) control groups reflected children with clinical problems.

This review makes an important contribution to the literature by analyzing studies based on the **level of evidence** as well as examining specific outcome areas. Low-level evidence includes such things as expert opinion and case reports; the highest level of evidence is reflected in randomized controlled trials and meta-analyses. Levels of evidence are often depicted using a pyramid, such as that in Figure 15-3a, or a table, as in Figure 15-3b.

Reported are 13 level I randomized controlled trials, five level II studies, three level III studies, and six level VI studies. Results are as follows: In the area of motor performance, improvements were noted in 10 out of 14 studies for fine and gross motor skills (Fig. 15-4), motor planning abilities, and participation in gross and fine motor play. In terms of sensory processing, seven out of 13 studies reported a positive outcome including improvements in sensory discrimination, a reduction in sensory defensiveness, and changes in physiological sensory reactivity. Behavioral outcomes were identified in six studies reporting changes in attention, self-esteem, social interaction, and decreased disruptive behaviors. Academic and psychoeducational outcomes were used in 12 studies, with six showing positive gains in such skills as reading, math, and visual performance. Overall findings suggested that these gains were at least as positive as gains

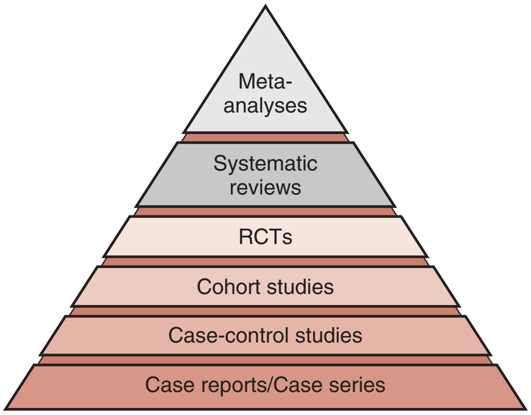

FIGURE 15-3a When a pyramid is used to depict levels of evidence, then level I is the highest.

FIGURE 15-4 Sensory integrative intervention has been shown to help improve motor planning abilities and increase children's participation in gross and fine motor play.

Strength	Level	Design	Randomization	Control
High	Level 1	Randomized control trial (RCT)	Yes	Yes
		Meta-analysis of RCT with homogeneous results	No	
	Level 2	Prospective comparative study (therapeutic)	No	Yes
		Meta-analysis of Level 2 studies or Level 1 studies with inconsistent results	No	
	Level 3	Retrospective cohort study	No	Yes
		Case-control study	No	Yes
		Meta-analysis of Level 3 studies	No	
	Level 4	Case series	No	No
	Level 5	Case report	No	No
		Expert opinion	No	No
Low		Personal observation	No	No

FIGURE 15-3b The benefit of using a table to present levels of evidence is that it includes the numeric levels.

achieved by alternative interventions. Only three studies examined changes in occupational performance outcomes using individualized goals. Most promising for future research, all these studies demonstrated significant gains in parent-identified goals.

Miller and colleagues' treatment studies, included in the previous review (Miller, Coll, & Schoen, 2007; Miller, Schoen, James, & Schaaf, 2007), attempted to correct previous research limitations by utilizing a homogeneous sample, manualized treatment, outcome measures sensitive to change from treatment, and rigorous methodology. Results of the pilot treatment study (without control groups) demonstrated significant pre-post changes from treatment (Miller, Schoen, et al., 2007) and provided needed data for implementing a randomized treatment trial. Subsequently, Miller and colleagues (Miller, Coll, et al., 2007) conducted a pilot randomized controlled trial of the effectiveness of occupational therapy in children with a sensory integrative disorder. They evaluated the effectiveness of three treatment groups: occupational therapy, an active placebo called the Activity Protocol (a play protocol), and a passive placebo (e.g., wait-list condition). Twenty-four children were randomly assigned to one of the three treatment conditions. Pre- and post-measures of behavior, sensory function, adaptive function, and physiology were administered. The manualized treatment was administered twice a week for 10 weeks in 50-minute sessions. Fidelity to the treatment protocol, or the extent to which the treatment was carried out as intended, was analyzed using a Fidelity Measure created for this study and later expanded for future research (Parham, Ecker, et al., 2007). The Fidelity Measure captures the structural and process elements that are core to SI intervention. Results demonstrated that the group that received occupational therapy, compared with the other two groups, made significant gains on individualized goals using **Goal Attainment Scaling** (GAS) ($p < 0.001$), on attention measures, and on the Cognitive/Social Composite of the Leiter International Performance Scale-Revised (Roid & Miller, 1997) ($p = 0.02$). For both the Short Sensory Profile (SSP) total test score and the Child Behavior Checklist (CBCL) internalizing composite score, change scores were greater, but not significant, in the hypothesized direction for the occupational therapy group. Physiologically, a small subsample of the occupational therapy group showed greater reduction in amplitudes of electrodermal reactivity (EDR) compared with the other two groups, although not significant due likely to the small sample size.

Since publication of these pilot studies, there have been two additional randomized controlled trials published, one conducted by Pfeiffer and colleagues (2011) and the other by Schaaf and colleagues (2014). Both studies addressed the question of effectiveness of SI intervention for children with ASD.

The pilot treatment study by Pfeiffer and colleagues (2011) sought to expand on Miller's model for randomized controlled trial research and to identify appropriate outcome measures for children with autism spectrum disorder. Thirty-seven children between 6 and 12 years of age participated; five were female. Intervention consisted of eighteen 45-minute sessions during a 6-week period. Twenty children received SI intervention, and 17 received a fine motor intervention. Fidelity to treatment was examined by scoring videotaped sessions using the fidelity instruments. Results showed significant improvement in autism mannerisms and significant progress toward individualized goals. No significant differences were found in sensory processing as measured by the SPM (Parham, Ecker, et al., 2007) or in neurological integration as measured by the Quick Neurological Screening Test-3 (Mutti, Martin, Sterling, & Spalding, 2011). These findings supported earlier findings obtained by Watling and Dietz (2007) and Smith and colleagues (2005). In particular, in a single-subject multiple-baseline design of four children with ASD, Watling and Dietz (2007) found a reduction in stereotypical movement patterns after a latency period, although not immediately after treatment. Similarly, Smith and colleagues (2005) conducted a two-group non-randomized controlled trial with seven adolescents who were severely impaired with self-stimulatory and self-injurious behaviors. They found a reduction of 11% in self-stimulation at 1 hour post-intervention.

Schaaf and colleagues (2014) conducted a randomized controlled trial of SI intervention for 32 children from 4 to 8 years of age with ASD. Subjects were assigned randomly to the SI group or to the usual care control group. Treatment was provided in 1-hour sessions, three times a

PRACTICE WISDOM

Whether you are working with children with sensory integrative disorders in a clinic, community setting, or in a school, setting goals and measuring progress can be challenging. This is particularly true if you are trying to measure progress in a group of children who all have very specific needs and individualized goals. GAS has gained popularity during the past decade as a means of setting individualized goals but scaling them all in the same way as to allow meaningful comparisons. When using GAS, a specific goal is developed with the client and set on a scale that ranges from least to most favorable outcomes. Points on the scale are given objective descriptions and are assigned numerical values (for instance, –2 for the least favorable outcome, 0 for the most likely treatment outcome, and +2 for the most favorable treatment outcome). Thus, this scale has a mean value of zero and a standard deviation of 1. Although GAS has been used for goal setting in high-level research studies (see Miller, Coll, et al., 2007; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2014), it also may be useful in clinical settings for program evaluation and in schools for monitoring progress of students' individualized education plans. GAS has the advantage of being low cost and useful for tracking progress across a variety of treatment goals. One crucial challenge in establishing GAS goals is in defining the outcomes; the challenge for the child to move from a "0" to a "1" must be equivalent to the challenge in moving from a "1" to a "2." Outcomes must be considered carefully. Training in the use of GAS is available and will help in learning how to best establish outcome scales. Here is an example of how GAS could be used with a child with sensory integrative disorder:

Goal: Increase sequencing and planning abilities as a basis for getting ready for school in the morning.

Current Level of Functioning: At 12 years of age, Meghan currently needs 20 to 30 verbal prompts from her mother to sequence her morning routine, which includes getting dressed, putting on deodorant, brushing her teeth, eating breakfast, and packing her lunch and belongings for school. Even with support, Meghan almost always will leave the house having forgotten something.

Goal Attainment Scaling:

- +2 (most favorable outcome likely): Will get ready in the morning with 0 to 4 verbal prompts
- +1 (greater than expected outcome): Will get ready in the morning with 5 to 9 verbal prompts
- 0 (expected outcome): Will get ready in the morning with 10 to 14 verbal prompts
- –1 (less than expected outcome): Will get ready in the morning with 15 to 19 verbal prompts
- –2 (most unfavorable outcome): Will get ready in the morning with 20+ verbal prompts

week during 10 weeks. Building on the previous SI randomized controlled trials, this study utilized a manualized protocol and a validated measure of treatment fidelity (Parham, Ecker, et al., 2007; Parham et al., 2011). In addition, pre- and posttest evaluators were blind to each child's treatment condition. The primary findings of this study were as follows: Children in the SI group showed greater improvements in individualized goal attainment, needed significantly less caregiver assistance during self-care and social activities, and showed a decrease in sensory-related behaviors that interfere with daily life.

These positive preliminary findings suggest the need for completion of a larger randomized controlled trial of the effectiveness of occupational therapy using an SI treatment approach, so that a more definitive conclusion can be offered with reasonable assurance that results are not attributable to chance and that external and internal sources of invalidity have been fully controlled.

Future Directions

Based on the studies described previously, there are several factors that need to be considered in future research. Studies need to improve the **homogeneity** of the participants and increase sample sizes to improve statistical power. Further exploration of duration and intensity is needed as well as consistency across studies related to the frequency, duration, and amount of intervention provided. Studies need to focus on outcome measures that are meaningful and relevant to changes valued by clients and families and that are based on occupational performance or participation. In particular, measures of direct

HERE'S THE EVIDENCE

In their 2007 paper, "Fidelity in Sensory Integration Research," Parham, Cohn, and colleagues used expert review and a nominal group process to identify core SI intervention elements. Findings were organized into structural elements (observable and easily quantified characteristics, such as environmental features and professional training of the therapist) and process elements (dynamic qualities of the intervention, such as therapeutic alliance, which are often more difficult to measure). Structural elements of SI intervention identified in the literature included professional training of the interventionist who was usually an occupational therapist as well as the presence of equipment such as scooter boards, suspended equipment, and tactile materials. Core process elements of SI intervention were also identified and included provision of the following:

- Sensory opportunities
- Just-right challenges
- Collaboration with the child on activity choice
- Support for the child's self-organization
- Support for maintenance of optimal arousal
- Creating a context of play
- Maximizing the child's success
- Ensuring physical safety
- Arrangement of the room to entice engagement
- Fostering of a therapeutic alliance

The authors noted in their review that most published studies did not address fidelity in their research design and subsequently identified the need for a fidelity instrument to measure adherence to the underlying intervention principles related to Ayres Sensory Integration® (ASI) theory. In 2011, Parham and colleagues published a follow-up paper entitled "Development of a Fidelity Measure for Research on the Effectiveness of the Ayres Sensory Integration® Intervention." In this paper, a fidelity instrument intended to measure the structural and process aspects of ASI is presented along with assessment of the tool's reliability and validity. Overall, the tool was found to have strong content validity and was deemed to be reliable when scored by trained raters with expertise in ASI. These papers provide an outline of what should be included in interventions claiming to be SI intervention and provide a tool (the fidelity instrument) that can be used to enhance the rigor of clinical research.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J., Miller, L. J., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration research. *American Journal of Occupational Therapy, 61*(2), 216–227.

Parham, L. D., Smith Roley, S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on the effectiveness of the Ayres Sensory Integration® Intervention. *American Journal of Occupational Therapy, 65*(2), 133–142.

observation are needed to supplement existing caregiver questionnaires. Continued efforts need to be directed toward the development of intervention manuals that provide a description of the intervention along with a measure to demonstrate fidelity to the intervention. Although this is being done more often, we need to be consistent in using these tools. Most existing studies measured change immediately following intervention. However, what is not known is how long the effects of treatment last.

HERE'S THE POINT

- Research has shown that interventions using a sensory integrative approach improve motor planning, participation, motor skills, self-care, behavior, academic, and psycho-educational outcomes.
- Research on the effectiveness of sensory integrative intervention is ongoing, with studies aiming for greater power, consistency, and a focus on functional outcomes. Currently there is some evidence supporting sensory integration intervention as an evidence-based and effective intervention.

Research Related to the Disorders

Examination of sensory integrative disorders has focused most extensively on disorders of modulation and, within this category, on the identification and understanding of sensory over-responsiveness. There is some, albeit limited, data on sensory integrative disorders as a whole, and another body of investigation focused on praxis and postural control disorders. Research in each area will be summarized next.

Research Related to Impairments in Sensory Modulation and Sensory Integration

Pre- and perinatal birth factors have been associated with general sensory integrative problems. In a large retrospective sample of primarily Caucasian two-parent families, May-Benson, Koomar, and Teasdale (2009) found a relatively high incidence of prenatal stress and prenatal health-related problems in mothers of children with sensory integrative disorders, and with ASD with co-occurring sensory integrative disorders. Delivery complications were also reported for 37% to 42% of this sample, and a higher percentage of assisted deliveries (e.g., C-section, induced labor) were reported in the group with ASD and co-occurring SPD (43.5%). Factors such as birth weight and gestational age, which have been suggested as potential risk factors for sensory integrative disorders and autism, were not significantly higher in this population as compared with the national average.

In both children and adults, a growing body of literature supports the relationship between sensory integrative disorders and significant impairments in the ability to perform daily routines. Sensory processing is cited as a foundational ability contributing to the acquisition of higher order functions (Cheng & Boggett-Carsjens, 2005) such as affect regulation (Fig. 15-5). Other studies document social, emotional, and behavioral disturbances in children with sensory integrative disorders (Cohn, Miller, & Tickle-Degnen, 2000; Kinnealey, 1998; Roberts, King-Thomas, & Boccia, 2007). In particular, the following impairments have been highlighted: decreased engagement, poor socialization, poor self-regulation, low self-confidence and self-esteem, and decreased functional competence (Cohn et al., 2000), success, enjoyment, and frequency of performing functional activities (Bar-Shalita et al., 2008). Performance can be affected in all areas of daily function, including self-care, home and academic activities, play, leisure activities, and daily habits and routines (Bar-Shalita et al., 2008; White, Mulligan, Merrill, & Wright, 2007). In addition, sensory integrative disorders impact family function, affect the ability to complete self-care activities (grooming, dressing, eating), and impact the ability to communicate or engage in fine or gross motor activities (Kinnealey, 1998).

FIGURE 15-5 Research suggests that sensory over-responsivity in children may limit the family's ability to participate in desired routines, leading to feelings of isolation.

Finally, Carter, Ben-Sasson, and Briggs-Gowan (2011) examined the impact of SOR in children from 7 to 11 years of age (n = 413) on family life using the Family Life Impairment Scale (FLIS; Briggs-Gowan, Horwitz, & Carter, 1997). Mothers of children who had SOR reported greater amounts of family impairment than mothers of children with either externalizing or internalizing symptoms alone.

The impact of disorders of SI into adulthood is highlighted in the research of Kinnealey and Fuiek (1999). Adults with SMD require excessive time and energy to cope with and recuperate from daily life routines. They tend to isolate themselves, which affects their ability to fully participate and engage in the range of everyday activities that most adults enjoy (Kinnealey, Oliver, & Wilbarger, 1995; Pfeiffer & Kinnealey, 2003). Also associated are physical and social isolation, poor social skills, decreased participation in social roles, and decreased involvement in community activities (Kinnealey & Fuiek, 1999; Kinnealey, Koenig, & Smith, 2011; Pfeiffer, Kinnealey, Reed, & Herzberg, 2005). Reports of increased anxiety and depression have been noted in adults with sensory integrative disorders (Kinnealey & Fuiek, 1999). In addition, adults with sensory integrative disorders have fewer perceived social supports and lower health-related quality of life scores in the areas of bodily pain, general health vitality, and social functioning (Kinnealey et al., 2011). Thus, disorders of sensory modulation were found to be a risk factor for health-related problems.

Research Related to Prevalence, Risk Factors, and Clinical Presentation

Research related to the uniqueness or distinctiveness of sensory integrative disorders in large part comes from studies that were conducted in an effort to obtain recognition of these disorders in the *Diagnostic and Statistical Manual of Mental Disorders,* Fifth Edition *(DSM-5).* This work, spearheaded by Dr. Lucy Jane Miller, focused on SOR because it had the greatest amount of face validity (e.g., the symptoms are readily observable and consistently result in referrals for treatment). However, research is accumulating related to SMD more broadly as well.

Although sensory modulation difficulties have been described in diagnostic groups for many years, the presence of SMD in the absence of other clinical conditions provides an important foundation for understanding this disorder. Characteristics elucidated through case study presentation, and prevalence estimates and longitudinal studies, provide additional evidence.

Reynolds and Lane (2008) presented a detailed multiple case study on three children with SOR, documenting the independent existence of SOR. Careful testing ensured that the sample had average intelligence and no other comorbid diagnosis, thus excluding common comorbid conditions such as autism and ADHD, along with other mental health and stress-related disorders. The sensory processing profiles of the sample included actively avoiding stimuli as well as defensive or sensitive responses to stimuli perceived as unpleasant. Parents indicated that their children became overwhelmed in certain environments and showed strong emotional reactions to some sensory stimuli, resulting in disruptive or aggressive behaviors.

Two primary research teams provide broader support for the distinctiveness of SMD compared with other established diagnostic categories. In a recent study, Goldsmith and colleagues (Van Hulle, Schmidt, & Goldsmith, 2012) screened 765 school-aged children for both SOR (either tactile or auditory) and common diagnoses reported in the *DSM-5* (American Psychiatric Association, 2013). Approximately 58% of the children who screened positive for SOR did not qualify for any other *DSM* diagnosis. Analyses were conducted that ruled out physical health problems as the source of SOR. Similarly, Carter and colleagues (2011) found that 75% of children identified with elevated SOR symptoms did not qualify for any other *DSM* diagnosis. Additionally, parents of children with increased SOR reported greater restrictions in their social lives (e.g., "I rarely take the child to visit friends or family," "We rarely leave the child with relatives") and personal lives (e.g., "I am usually exhausted all day," "We rarely make changes in daily schedule"), independent of sociodemographic risk.

Examination of prevalence of SMD in a non-referred population of children began with a small population-based study of kindergarten-aged students in one school district (n = 703) (Ahn, Miller, Milberger, & McIntosh, 2004). Results defined a conservative prevalence estimate of 5.3% of the sample who met criteria for SMD based on parental report using the SSP (McIntosh, Miller, Shyu, & Dunn, 1999). In a larger population-based study of SOR, data from 1,394 toddler-aged twins indicated rates of SOR that ranged from 2.8% to 6.5% (Goldsmith, Van Hulle, Arneson, Schreiber, & Gernbacher, 2006). There was also a strong association between SOR and fear-related aspects of temperament and anxiety, including object fear, social fear, sadness, and anger. Findings also suggested that children with SOR were at greater risk for internalizing problems, dysregulation problems, and maladaptive problems.

Higher prevalence was identified in a large sample of elementary school-aged children (followed as part of a longitudinal prospective birth cohort in the Greater New Haven area [n = 925]). Investigators (Ben-Sasson, Carter, & Briggs 2009) used the Sensory Over-Responsivity Scales (Schoen et al., 2008), now a part of the Sensory Processing Scale (SP Scale), with a validated cutoff score provided by the scale authors, and they reported that 16.5% of children from 7 to 11 years of age had elevated levels of tactile or auditory over-responsivity. Associated with elevated SOR behaviors were such risk factors as having a single parent and living in poverty. Parents of children with SOR reported more social-emotional problems and concerns regarding social competence in their children at school age; children with SOR were also four times more likely to have clinically significant internalizing problems and three times more likely to have clinically relevant externalizing problems.

SMD prevalence and the occurrence of comorbid psychiatric disorder was examined in a racially and ethnically diverse sample of preschoolers (n = 696) recruited from a 3-year longitudinal study on the development of oppositional defiant disorder, anxiety, and depression in young children (Gouze, Hopkins, Lebailly, & Lavigne, 2009). Depending on the criteria used, overall prevalence rates varied from 3.4% to 15.6%. No ethnic or racial differences appeared; however, more symptoms were reported in males. Depending on the sensory scale or criteria used to define SMD, between 37% and 67% of the children identified with SMD did not meet criteria for a psychiatric disorder. This data suggests that SMD exists independent of psychiatric disorder but is also a significant risk factor for other childhood psychopathology.

In addition to prevalence, the developmental trajectory of children identified in early childhood with SOR was examined at four time-points between infancy and early elementary school (Ben-Sasson, Carter, & Briggs-Gowan, 2010). Data were collected using the Infant-Toddler Social Emotional Assessment (ITSEA) (Briggs-Gowan, Carter, Bosson-Heenan, Guyer, & Horwitz, 2006) and the SP Scale (Schoen et al., 2008). Results indicated that children with elevated levels of SOR between 11 and 24 months of age, or children who showed significant increases in SOR symptoms from 11 to 51 months of age, tended to have greater SOR symptoms at 7 to 10 years of age. This study suggests that SOR symptoms are relatively stable in the general population.

Symptoms of SOR have also been reported in more diverse groups. For example, Gouze and colleagues (2009), cited previously, included an ethnically varied population in their study. Reynolds and Lane (2008) reported elevated levels of SMD symptoms in a Head Start population consisting of primarily minority and lower income families.

These data collectively indicate that SMD can be identified in children with no other diagnoses, or in conjunction with several mental health disorders; it is found across racial and ethnic groups, and prevalence varies considerably. More information is needed to define optimal identification, utilizing tools of direct observation as well as parent report. There also appear to be early indicators placing children at risk of developing SMD. Although we do not yet know the cause(s) of SMD subtypes, research using primate models provides some evidence that SOR may be attributed, at least in part, to factors such as lead exposure, prenatal alcohol exposure, and prenatal stress (Moore et al., 2008; Schneider et al., 2008), factors that may be more common in low-income and urban communities (Gee & Payne-Sturges, 2004). Another explanation for higher rates of SMD in children from families with lower income may be the living conditions and family environments associated with poverty. With some indicators that poorer families live in more crowded, noisier, and less structured and predictable households (Brody & Flor, 1997; Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005), it is possible that these contextual factors may contribute to the manifestation of SMD in children who are already genetically susceptible to this disorder.

Investigations have begun examining a potential genetic basis for SOR. Studies conducted with non-human primates at the Harlow Laboratory at the University of WI-Madison examined potential etiological factors and interactions with genetic variation, controlling for and manipulating environmental factors (Schneider et al., 2009). More than 10,000 monkeys born at the Harlow Primate Laboratory in Madison, Wisconsin, from the 1950s to the present (10 to 12 generations) were entered into a genetic program. Investigators concluded that the relationship between the phenotype presented (e.g., the magnitude of the sensory responses [degree of withdrawal or over-responsivity]) and genetic relatedness were statistically significant, providing preliminary, but quite convincing, evidence that the etiology of SOR may have a genetic influence.

Paralleling this work, Goldsmith and colleagues used a population-based sample of 1,394 twin pairs (mean 27 months of age) to examine genetic influences on tactile and auditory over-responsivity (Goldsmith et al., 2006, Fig. 15-6). If genetic effects are present, classic genetic assumptions imply that identical (MZ) twins, who share 100% of their genes, should be more similar than fraternal (DZ) twins, who share only 50% of segregating genes, on the average. Concordance rates for auditory SOR were MZ = 0.72 and DZ = 0.53, and for tactile SOR were MZ = 0.82 and DZ = 0.27, suggesting that SOR has moderate genetic influences with tactile over-responsivity

FIGURE 15-6 Twin studies provide a mechanism for assessing how much genes influence the development of sensory integrative disorders.

demonstrating somewhat greater heritability than auditory over-responsivity.

Future Directions

Future research into the prevalence of SMD across a range of racial and socio-economic groups is warranted, and specific focus should be placed on increasing our overall knowledge of which factors contribute to the development of or exacerbation of specific sensory behaviors (e.g., under-responsivity, over-responsivity). Understanding the association between sensory symptoms within families will also contribute to this knowledge as well as identification of early risk factors in siblings of children with sensory modulation or integration disorders. It is likely that future studies in behavioral and molecular genetics will play a significant role in helping the health community to classify and identify individuals who are predisposed to SMD and conditions such as autism in which they often co-occur.

HERE'S THE POINT

- Disorders in SI may be a risk factor for other health-related problems and can impact both the individual's and family's function and participation.
- Research suggests that SMD, specifically SOR, exists independent of other psychiatric conditions, but is also a risk factor for other childhood psychopathology.
- SOR has a strong genetic basis, but it may be influenced by environmental factors (e.g., prenatal alcohol use or lead exposure, family poverty) or issues related to the child's birth (e.g., delivery complications).

Summary and Conclusions

We are making progress toward a better understanding of SI dysfunction. Research using factor analyses supports consistency in the identification of patterns of sensory integrative dysfunction using existing and emerging assessment tools. In addition, recent high-quality effectiveness research has shown positive outcomes for many domains of child and family life. Our understanding of SOR has expanded; we know that it is identified both with and without other childhood disorders, that there appears to be a genetic link, and that there also may be contextual risk factors associated with its expression. There is much yet to be done, and our ongoing research must be of high quality. We need greater research rigor (e.g., increased statistical power, consistent use of intervention fidelity tools, identification of outcomes that are meaningful to child and family) as we move forward and answer increasingly complex questions.

Where Can I Find More?

Law, M., & MacDermid, J. (Eds.). (2014). *Evidence-based rehabilitation: A guide to practice.* Thorofare, NJ: Slack Inc.

Miller, L. J., & Roetenberg, J. (2014). *Sensational kids: Hope and help for children with sensory processing disorder (SPD).* New York, NY: Perigee Books.

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration®: Promoting participation for children with autism.* Bethesda, MD: American Occupational Therapy Association, Inc.

References

Ahn, R. R., Miller, L. J., Milberger, S., & McIntosh, D. N. (2004). Prevalence of parents' perceptions of sensory processing disorders among kindergarten children. *American Journal of Occupational Therapy, 58,* 287–302.

American Academy of Pediatrics, Section on Complementary and Integrative Medicine and Council on Children with Disabilities. (2012). Sensory integration therapies for children with developmental and behavioral disorders. *Pediatrics, 129,* 1186–1190. doi:10.1542/peds.2012-0876

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. Washington, DC: American Psychiatric Association.

American Occupational Therapy Association & American Occupational Therapy Foundation. (2011). Occupational therapy research agenda. *American Journal of Occupational Therapy*, *65*(Suppl.), S4–S7. doi:10.5014/ajot.2011.65S4

Arendt, R. E., MacLean, W. E., & Baumeister, A. (1988). Critique of sensory integration theory and its application in mental retardation. *American Journal of Mental Deficiency, 92,* 401–429.

Ayres, A. J. (1969). Deficits in sensory integration in educationally handicapped children. *Journal of Learning Disabilities, 2*(3), 44–52.

Ayres, A. J. (1972a). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1972b). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy, 26*(1), 13–18.

Ayres, A. J. (1977). Cluster analyses of measures of sensory integration. *American Journal of Occupational Therapy, 31*(6), 362–366.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests*. Los Angeles, CA: Western Psychological Services.

Bagatell, N., Mirigliani, G., Patterson, C., Reyes, Y., & Test, L. (2010). Effectiveness of therapy ball chairs on classroom participation in children with autism spectrum disorders. *American Journal of Occupational Therapy, 64,* 895–903. doi:10.5014/ajot.2010.09149

Baranek, G. T. (1998). *Tactile Defensiveness and Discrimination Test: Revised*. Unpublished Manuscript, University of North Carolina at Chapel Hill.

Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. *American Journal of Mental Retardation, 112,* 233–245.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, 47,* 591–601.

Bar-Shalita, T., Vatine, J., & Parush, S. (2008). Sensory modulation disorder: A risk factor for participation in daily life activities. *Developmental Medicine and Child Neurology, 50,* 932–937.

Bauer, B. A. (1977). Tactile sensitivity: Development of a behavioral responses checklist. *American Journal of Occupational Therapy, 31,* 357–361.

Ben-Sasson, A., Carter, A. S., & Briggs, M. J. (2009). Sensory over-responsivity in elementary school: Prevalence and social-emotional correlates. *Journal of Abnormal Child Psychology, 37,* 705–716. doi:10.1007/s10802-008-9295-8

Ben-Sasson, A., Carter, A. S., & Briggs-Gowan, M. J. (2010). The development of sensory over-responsivity from infancy to elementary school. *Journal of Abnormal Child Psychology, 38*(8), 1193–202. doi:10.1007/s10802-010-9435-9

Boruch, R. F. (1997). *Randomized experiments for planning and evaluation: A practical guide*. Thousand Oaks, CA: SAGE Publications.

Briggs-Gowan, M. J., Carter, A. S., Bosson-Heenan, J., Guyer, A. E., & Horwitz, S. M. (2006). Are infant-toddler social-emotional and behavioral problems transient? *Journal of the American Academy of Child and Adolescent Psychiatry, 45,* 849–858.

Briggs-Gowan, M. J., Horwitz, S. M., & Carter, A. S. (1997). *The Family Life Impairment Scale*. New Haven, CT: Yale University.

Brody, G. H., & Flor, D. L. (1997). Maternal psychological functioning, family processes, and child adjustment in rural, single-parent, African American families. *Developmental Psychology, 33*(6), 1000–1111.

Brown, C. E., & Dunn, W. (2002). *Adolescent/adult sensory profile: User's manual*. San Antonio, TX: Therapy Skill Builders.

Bulpitt, C. J. (1983). *Randomized controlled clinical trials*. Hingham, MA: Kluwer Boston.

Bury, T. J., & Mead, J. M. (Eds.). 1998. *Evidence-based health-care. A practical guide for therapists*. Oxford: Butterworth Heinemann.

Carrasco, R. C. (1991). A comparison of scores achieved by gifted and by talented public school children on the Sensory Integration and Praxis Test battery. *Dissertation Abstracts International, 52,* 561–562.

Carter, A. S., Ben-Sasson, A., & Briggs-Gowan, M. J. (2011). Sensory over-responsivity, psychopathology, and family impairment in school-aged children. *Journal of the American Academy of Child and Adolescent Psychiatry, 50*(12), 1210–1219. doi:10.1016/j.jaac.2011.09.010

Case-Smith, J., Weaver, L. L., & Fristad, M. A. (2015). A systematic review of sensory processing interventions for children with autism spectrum disorders. *Autism, 19*(2), 133–148. doi:10.1177/1362361313517762 aut.sagepub.com

Cheng, M., & Boggett-Carsjens, J. (2005). Consider sensory processing disorders in the explosive child: Case report and review. *The Canadian Child and Adolescent Psychiatry Review, 14,* 44–48.

Cohn, E., Miller, L. J., & Tickle-Degnen, L. (2000). Parental hopes for therapy outcomes: Children with sensory modulation disorders. *American Journal of Occupational Therapy, 54,* 36–43.

Cox, A. L., Gast, D. L., Luscre, D., & Ayres, K. M. (2009). The effects of weighted vests on appropriate in-seat behaviors of elementary-age students with autism and severe to profound intellectual disabilities. *Focus on Autism and Other Developmental Disabilities, 24*(1), 17–27.

Davis, T. N., Durand, S., & Chan, J. M. (2011). The effects of a brushing procedure on stereotypical behavior. *Research in Autism Spectrum Disorders, 5*(3), 1053–1058.

Devlin, S., Healy, O., Leader, G., & Hughes, B. M. (2009). Comparison of behavioral intervention and sensory-integration therapy in the treatment of challenging behavior. *Journal of Autism and Developmental Disorders, 41*(10), 1303–1320. doi:10.1007/s10803-010-1149-x

Dunn, W. (1999). *The Sensory Profile*. San Antonio, TX: Psychological Corporation.

Dunn, W. (2006). *School companion sensory profile manual*. San Antonio, TX: Psychological Corporation.

Dunn, W. (2014). *Sensory Profile™ 2*. San Antonio, TX: The Psychological Corporation.

Evans, G. W., Gonnella, C., Marcynyszyn, L. A., Gentile, L., & Salpekar, N. (2005). The role of chaos in poverty and children's socioemotional adjustment. *Psychological Science, 16*(7), 560–565.

Fazlioglu, Y., & Baran, G. (2008). A sensory integration therapy program on sensory problems for children with autism. *Perceptual and Motor Skills, 106*(2), 355–370.

Fertel-Daly, D., Bedell, G., & Hinojosa, J. (2001). Effects of a weighted vest on attention to task and self-stimulatory behaviors in preschoolers with pervasive developmental disorders. *American Journal of Occupational Therapy, 55,* 629–640. doi:10.5014/ajot.55.6.629

Friedman, L. M., Furberg, C. D., & DeMets, D. L. (2015). *Fundamentals of clinical trials* (5th ed.). Basil, Switzerland: Springer International Publishing.

Fuhrer, M. J. (1997). *Assessing medical rehabilitation practices: The promise of outcomes research*. Baltimore, MD: Paul H. Brookes Publishing Co.

Gee, G. C., & Payne-Sturges, D. C. (2004). Environmental health disparities: A framework integrating psychosocial and environmental concepts. *Environmental Health Perspectives, 112*(17), 1645–1653.

Goldsmith, H. H., Van Hulle, C. A., Arneson, C. L., Schreiber, J. E., & Gernsbacher, M. A. (2006). A population-based twin study of parentally reported tactile and auditory defensiveness in young children. *Journal of Abnormal Child Psychology, 34,* 393–407.

Gouze, K. R., Hopkins, J., Lebailly, S. A., & Lavigne, J. V. (2009). Re-examining the epidemiology of sensory regulation dysfunction and comorbid psychopathology. *Journal of Abnormal Child Psychology, 37*(8), 1077–1087.

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. (2011a). Effects of weighted vests on classroom behavior for children with autism and cognitive impairments. *Research in Autism Spectrum Disorders, 5,* 495–505. doi:10.1016/j.rasd.2010.06.015

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. (2011b). Weighted vests, stereotyped behaviors and arousal in children with autism. *Journal of Autism and Developmental Disorders, 41,* 805–814. doi:10.1007/s10803-010-1104-x

Hoehn, T. P., & Baumeister, A. A. (1994). A critique of the application of sensory integration therapy to children with learning disabilities. *Journal of Learning Disabilities, 27,* 338–350.

ICDL-DMIC Work Groups. (2005). *Diagnostic Manual for Infancy and Early Childhood: Mental Health, Developmental, Regulatory-Sensory Processing and Language Disorders and Learning Challenges (ICDL-DMIC)*. Bethesda, MD: Interdisciplinary Council on Developmental and Learning Disorders (ICDL).

Jadad, A. R. (1998). *Randomized controlled trials*. Malden, MA: Blackwell Publishing.

Kane, A., Luiselli, J., Dearorn, S., & Young, N. (2004). Wearing a weighted vest as intervention for children with autism and pervasive developmental disorder. *The Scientific Review of Mental Health Practice, 3*(2), 19–24.

Kientz, M. A., & Dunn, W. (1997). A comparison of the performance of children with and without autism on the sensory profile. *American Journal of Occupational Therapy, 51,* 530–537.

Kinnealey, M. (1973). Aversive and nonaversive responses to sensory stimulation in mentally retarded children. *American Journal of Occupational Therapy, 27,* 464–471.

Kinnealey, M. (1998). Princess or tyrant: A case report of a child with sensory defensiveness. *Occupational Therapy International, 5,* 293–303.

Kinnealey, M., & Fuiek, M. (1999). The relationship between sensory defensiveness, anxiety, depression and perception of pain in adults. *Occupational Therapy International, 6,* 195–206.

Kinnealey, M., Koenig, K. P., & Smith, S. (2011). Relationships between sensory modulation and social supports and health related quality of life. *American Journal of Occupational Therapy, 65,* 320–327. doi:10.5014/ajot.2011.001370

Kinnealey, M., Oliver, B., & Wilbarger, P. (1995). A phenomenological study of sensory defensiveness in adults. *American Journal of Occupational Therapy, 49,* 444–451.

Lai, J. S., Fisher, A. G., Magalhaes, L. C., & Bundy, A. C. (1996). Construct validity of the Sensory Integration and Praxis Tests. *OTJR: Occupation, Participation and Health, 16,* 75–97.

Leekam, S. R., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders, 37,* 894–910.

Leekam, R. S., Libby, S. J., Wing, L., Gould, J., & Taylor, C. (2002). The Diagnostic Interview for Social and Communication Disorders: Algorithms for ICD-10 childhood autism and Wing and Gould autistic spectrum disorder. *Journal of Child Psychology and Psychiatry, 43,* 327–342.

Leew, S. V., Stein, N. G., & Gibbard, W. B. (2010). Weighted vests' effect on social attention for toddlers with autism spectrum disorders. *Canadian Journal of Occupational Therapy, 77,* 113–124. doi: 10.2182/cjot.2010.77.2.7

Mailloux, Z., Mulligan, S., Smith Roley, S., Blanche, E., Cermak, S., Coleman, G., . . . Lane, C. J.

(2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy, 65*(2), 143–151.

Mailloux, Z., Parham, L. D., Roley, S. S., Ruzzano, L., & Schaaf, R. C. (2018). Introduction to the Evaluation in Ayres Sensory Integration® (EASI). *American Journal of Occupational Therapy, 72*(1), 7201195030p1–7201195030p7.

May-Benson, T., Koomar, J. A., & Teasdale, A. (2009). Incidence of pre-, peri-, and post-natal birth and developmental problems of children with sensory processing disorder and children with autism spectrum. *Frontiers in Integrative Neuroscience, 3*, 31. doi:10.3389/neuro.07.031.2009.

May-Benson, T. A., & Koomar, J. A. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy, 64,* 403–414. doi:10.5014/ajot.2010.09071

McIntosh, D. N., Miller, L. J., Shyu, V., & Dunn, W. (1999). Overview of the Short Sensory Profile (SSP). In W. Dunn (Ed.), *The Sensory Profile: Examiner's manual* (pp. 59–73). San Antonio, TX: The Psychological Corporation.

Miller, L. J. (2003). Empirical evidence related to therapies for sensory processing impairments. *Communiqué, 31,* 34–37.

Miller, L. J. (2012). Letter to the editor re: sensory integration therapies for children with developmental and behavioral disorders. Downloaded 4-22-2019 from https://pediatrics.aappublications.org/content/129/6/1186.

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *American Journal of Occupational Therapy, 61,* 228–238.

Miller, L. J., Schoen, S. A., James, K., & Schaaf, R. C. (2007). Lessons learned: A pilot study on occupational therapy effectiveness for children with sensory modulation disorder. *American Journal of Occupational Therapy, 61,* 161–169.

Minshew, N. J., & Hobson, J. A. (2008). Sensory sensitivities and performance on sensory perceptual tasks in high-functioning individuals with autism. *Journal of Autism and Developmental Disorders, 38,* 1485–1498.

Moore, C. F., Gajewski, L. L., Laughlin, N. K., Luck, M. L., Larson, J. A., & Schneider, M. J. (2008). Developmental lead exposure induces tactile defensiveness in rhesus monkeys (Macaca mulatta). *Environmental Health Perspectives, 116,* 1322–1326.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy, 52*(10), 819–828.

Mutti, M., Martin, N. A., Sterling, H. M., & Spalding, N. V. (2011). *Quick Neurological Screening Test-3*. Los Angeles, CA: Western Psychological Services.

Ottenbacher, K. (1982a). Patterns of postrotary nystagmus in three learning-disabled children. *American Journal of Occupational Therapy, 36,* 657–663.

Ottenbacher, K. (1982b). Sensory integration therapy: Affect or effect. *American Journal of Occupational Therapy, 36,* 571–578.

Ottenbacher, K. (1991). Research in sensory integration: Empirical perceptions and progress. In A. G. Fisher, E. A. Murray, & A. C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 385–399). Philadelphia, PA: F.A. Davis Company.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61,* 216–227.

Parham, L. D., Ecker, C., Miller Kuhaneck, H., Henry, D. A., & Glennon, T. J. (2007). *Sensory Processing Measure (SPM): Manual*. Los Angeles, CA: Western Psychological Services.

Parham, L. D., Ecker, C., Kuhaneck, H. M., Henry, D. A., & Glennon, T. J. (2010). *Sensory Processing Measure (SPM): Manual*. Los Angeles, CA: Western Psychological Services.

Parham, L. D., Smith Roley, S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on the effectiveness of the Ayres Sensory Integration® intervention. *American Journal of Occupational Therapy, 65*(2), 133–142. doi:10.5014/ajot.2011.000745

Pearson. (2005). Adolescent/Adult Sensory Profile technical summary. Downloaded 7-31-2015 from http://www.pearsonclinical.com/therapy/products/100000434/adolescentadult-sensory-profile.html#tab-resources

Pearson. (2014). Sensory Profile 2 technical summary. Downloaded 7-31-2014 from http://www.pearsonclinical.com/therapy/products/100000822/sensory-profile-2.html#tab-resources

Pfeiffer, B., & Kinnealey, M. (2003). Treatment of sensory defensiveness in adults. *Occupational Therapy International, 10,* 175–184.

Pfeiffer, B., Kinnealey, M., Reed, C., & Herzberg, G. (2005). Sensory modulation and affective disorders in children and adolescents with Asperger's disorder. *American Journal of Occupational Therapy, 59,* 335–345.

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy, 65*(1), 76–85. doi:10.5014/ajot.2011.09205

Polatajko, H. J., Kaplan, B. J., & Wilson, B. N. (1992). Sensory integration treatment for children with learning disabilities: Its status 20 years later. *Occupational Therapy Journal of Research, 12,* 323–341.

Reichow, B., Barton, E. E., Sewell, J. S., Good, L., & Wolery, M. (2010). Effects of weighted vests on the engagement of children with developmental delays and autism. *Focus on Autism and Other Developmental Disabilities, 25,* 3–11. doi:10.1177/1088357609353751

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism and Developmental Disorders, 38,* 516–529.

Roberts, J. E., King-Thomas, L., & Boccia, M. L. (2007). Behavioral indexes of the efficacy of sensory integration therapy. *American Journal of Occupational Therapy, 61,* 555–562.

Roid, G. H., & Miller, L. J. (1997). *Leiter International Performance Scale-Revised*. Wood Dale, IL: Stoelting.

Royeen, C. B., Koomar, J., Cromack, T., & Fortune, J. C. (1991). Evidence for content and discriminant validity of the Sensory Integration and Praxis Tests Competency Exam. *Occupational Therapy Journal of Research, 11,* 357–366.

Royeen, C. R., & Mu, K. (2003). Stability of tactile defensiveness across cultures: European and American children's responses to the Touch Inventory for Elementary school aged children. *Occupational Therapy International, 10,* 165–174.

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kelly, D. (2014). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders, 44*(2014), 1493–1506. doi:10.1007/s10803-013-1983-8

Schaffer, R. (1984). Sensory integration therapy with learning disabled children: A critical review. *Canadian Journal of Occupational Therapy, 51,* 73–77.

Schilling, D. L., & Schwartz, I. S. (2004). Alternative seating for young children with autism spectrum disorder: Effects on classroom behavior. *Journal of Autism and Developmental Disorders, 34,* 423–434. doi:10.1023/B:JADD.0000037418.48587.f4

Schneider, M. J., Moore, C. F., Gajewski, L. L., Larson, J. L., Roberts, A. D., Converse, A. K., & DeJesus, O. T. (2008). Sensory processing disorder in a primate model: Evidence from a longitudinal study of prenatal alcohol and prenatal stress effects. *Child Development, 79,* 100–113.

Schneider, M. J., Moore, C. F., Larson, J. L., Barr, C. S., DeJesus, O. T., & Roberts, A. D. (2009). Timing of moderate level prenatal alcohol exposure influences gene expression of sensory processing behavior in rhesus monkeys. *Frontiers in Integrative Neuroscience, 3,* 30. doi:10.3389/neuro.07.030.2009

Schoen, S. A., Miller, L. J., & Green, K. E. (2008). Pilot study of the sensory over-responsivity scales: Assessment and inventory. *American Journal of Occupational Therapy, 62,* 393–406.

Schoen, S. A., Miller, L. J., & Sullivan, J. C. (2014). Measurement in sensory modulation: The Sensory Processing Scale Assessment. *American Journal of Occupational Therapy, 68,* 522–530. doi:10.5014/ajot.2014.012377

Schoen, S. A., Miller, L. J., & Sullivan, J. C. (2016). The development and psychometric properties of the Sensory Processing Scale Inventory: A report measure of sensory modulation. *Journal of Intellectual and Developmental Disability, 41,* 1–10.

Schoen, S. A., Lane, S. J., Mailloux, Z., May-Benson, T., Parham, L. D., Roley, S. S., & Schaaf, R. C. (2019). A systematic review of Ayres sensory integration intervention for children with autism. *Autism Research, 12,* 6–19. doi:10.1002/aur.2046

Smith, S. A., Press, B., Koenig, K. P., & Kinnealey, M. (2005). Effects of sensory integration intervention on self-stimulating and self-injurious behaviors. *American Journal of Occupational Therapy, 59,* 418–425.

Talay-Ongan, A., & Wood, K. (2000). Unusual sensory sensitivities in autism: A possible crossroads. *International Journal of Disability, Development and Education, 47,* 201–212.

Van Hulle, C. A., Schmidt, N. L., & Goldsmith, H. H. (2012). Is sensory over-responsivity distinguishable from childhood behavior problems? A phenotypic and genetic analysis. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 53*(1), 64–72. doi:10.1111/j.1469-7610.2011.02432.x

Van Rie, G. L., & Heflin, L. J. (2009). The effect of sensory activities on correct responding for children with autism spectrum disorders. *Research in Autism Spectrum Disorders, 3*(3), 783–796.

Vargas, S., & Camilli, G. (1999). A meta-analysis of research on sensory integration treatment. *American Journal of Occupational Therapy, 53,* 189–198.

Walker, K. F., & Burris, B. (1991). Correlation of the Sensory Integration and Praxis Tests with the Metropolitan Achievement Test scores in normal children. *Occupational Therapy Journal of Research, 11,* 307–310.

Watling, R. L., & Dietz, J. (2007). Immediate effect of Ayres's Sensory Integration-based occupational therapy intervention on children with autism spectrum disorders. *American Journal of Occupational Therapy, 61*(5), 574–583.

White, B. P., Mulligan, S., Merrill, S., & Wright, J. (2007). An examination of the relationships between motor and process skills and scores on the sensory profile. *American Journal of Occupational Therapy, 61,* 154–160.

Wing, L., Leekam, L., Libby, S., Gould, J., & Larcombe, M. (2002). The Diagnostic Interview for Social and Communication Disorders: Background, inter-rater reliability and clinical use. *Journal of Child Psychology and Psychiatry, 43,* 307–325.

Zero to Three. (2005). *Diagnostic classification of mental health and developmental disorders of infancy and early childhood: Revised edition* (DC:0-3R). Washington, DC: Zero to Three Press.

CHAPTER 16

Advances in Sensory Integration Research: Basic Science Research

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Why do we do basic science research? To learn about ourselves.

—Walter Gilbert

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Recognize and describe various measurement techniques currently being used to measure neurological processes associated with sensory integration.
- ✔ Describe brain regions and systems implicated in sensory integrative disorders.
- ✔ Describe how animal research can contribute to our understanding of sensory integrative disorders and sensory integration intervention.
- ✔ Compare and contrast neurological and physiological patterns in children with sensory integrative disorders with and without comorbid psychiatric conditions.

Introduction

Ayres' theory of sensory integration is heavily grounded in neuroscience literature and hypothesizes intimate links between brain and behavior. In order to make links between brain function and behavioral outcomes, however, a continuum of sensory integration research is required (Fig. 16-1). At one end of the continuum are studies that look at the efficacy or effectiveness of interventions for human subjects in laboratory or clinical settings. This type of research was described in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research), as was more translational research that focused on development of outcome measures and design of specific interventions. At the other end of the continuum are basic science research studies (sometimes called preclinical studies) that attempt to define mechanisms underlying disorders and identify potential targets for intervention (Fig. 16-1). This chapter will focus on these types of basic science studies.

At the heart of sensory integration theory and intervention is the belief that the brain is capable of change throughout the life span; changes in brain organization and connectivity are called **neuroplasticity.** As clinicians, we assume neuroplasticity is occurring when we see changes in performance or behavior. As clinical researchers, we endeavor to control for other factors that may also result in behavior or performance change, to allow us to suggest that our intervention approach is linked to behavioral and performance changes. However, basic science research allows us to examine structural changes that occur at the level of the individual neuron (e.g., enhancements in dendritic spine density or dendritic branching),

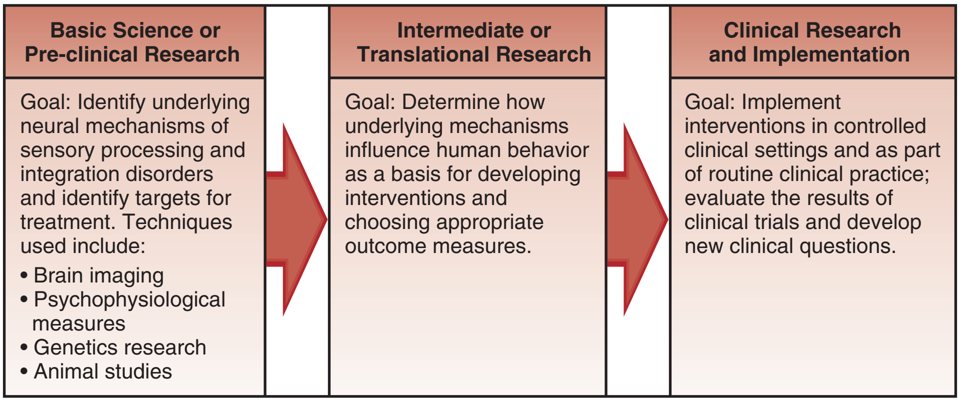

FIGURE 16-1 Continuum of sensory integration research.

in CNS regions (e.g., the autonomic nervous system), or in groups of neurons that form pathways in the brain.

Lane and Schaaf (2010)'s systematic review of the sensorimotor-based plasticity literature across various disciplines provides evidence to support the basic tenets of Ayres' theory. Specifically, this review demonstrates important links among sensory input, brain function, and behavior. They found that much of this literature focuses on animal studies that explored the impact of enriched environments on the structure and function of the nervous system. Among these studies, the most important findings were (1) increased dendritic branching, particularly in the occipital cortex, were evident in response to active engagement within enriched environments (Diamond, Rosenzweig, Bennett, Lindner, & Lyon, 1972; Kempermann & Gage, 1999; Mollgarard, Diamond, Bennett, Rosenzweig, & Lindner, 1971); (2) changes in neuronal structures were related to improved maze navigation performance, providing a link between structure and behavioral change (West & Greenough, 1972); and (3) links between improvements in motor performance and active participation inherently incorporate somatosensory feedback (Lacourse, Turner, Randolph-Orr, Schandler, & Cohen, 2004; Rosenzweig et al., 1969; Rosenzweig & Bennett, 1972).

The motor and neurological changes reported in this body of literature can occur very rapidly (Pantev et al., 2003) and can be long lasting (Stoeckel, Pollok, Schnitzler, Witte, & Seitz, 2004). It may be important to consider critical periods in sensory system influence (Bavelier et al., 2001; Zhang, Bao, & Merzenich, 2001) as well as evidence that suggests the benefit of multisensory experiences (Stein, Stanford, & Rowland, 2014).

Paralleling the development of this foundation, there is a branch of neuroscience currently engaged in the study of multisensory processing and integration. Advances in research evident in both basic multisensory processing and sensory integration have enhanced our understanding of the disorders and informed the treatment approach.

Ayres proposed that the subconscious, simultaneous interaction of multiple sensory systems is critical to how we make sense of daily sensory experiences. She stated, "Sensory integration sorts, orders and eventually puts all of the individual sensory inputs together into whole brain function" (Ayres, 1979, p. 28). This premise is well supported in a recent neuroscience study of multisensory integration, which suggests that the speed, efficiency, and meaning of experiences are enhanced through the transmission of multisensory inputs (Stein et al., 2014). Recent evidence suggests that multisensory integration (MSI) is acquired through experience and interaction with the environment. Documented in children as early as 3 to 5 months of age (Lewkowicz & Röder, 2012), the process is thought to experience the greatest maturation within the first 8 years of life (Ernst, 2008). Critical to understanding the advances in sensory integration is to recognize the contributions from both basic and applied science related to the underlying neurophysiology of the disorder and the value of multisensory strategies used in the intervention.

Purpose and Scope

This chapter focuses on the basic research related to sensory integration, focusing on MSI and sensory modulation. We will review research designed to gain a better understanding of the physiological mechanisms underlying sensory modulation, examine some of the research on animal models of sensory integration and processing deficits, and consider work being done on children with diagnoses that are comorbid with sensory disorders. This body of work extends our understanding of the neural processes associated with sensory integration and processing deficits, and it lays a foundation for understanding behavior. Specific links between the basic science findings and our understanding of sensory integration and processing deficits are suggested throughout.

There are many abbreviations used in the following summaries of existing basic research. We define each abbreviation in the text, and we have collected them together in Table 16-1.

TABLE 16-1 Table of Abbreviations

TERM	ABBREVIATION
Sensory modulation disorder	SMD
Autonomic nervous system	ANS
Sensory over-responsivity	SOR
Electrodermal response	EDR
Sensory Challenge Protocol	SCP
Evoked response potential	ERP
Electroencephalogram	EEG
Functional magnetic resonance imaging	fMRI
Positron emission tomography	PET
Magnetoencephalography	MEG
Diffusion tensor imaging	DTI
Attention deficit-hyperactivity disorder	ADHD
Multisensory integration	MSI
Autism spectrum disorder	ASD
Hypothalamic–pituitary–adrenal	HPA
Sensory Processing Scale for Monkeys	SPS-M
Borderline personality disorder	BPD
Somatosensory evoked potential	SEP
Electrodermal activity	EDA
Attention deficit-hyperactivity disorder with sensory over-responsivity	ADHDs
Attention deficit-hyperactivity disorder with typical sensory functioning	ADHDt

Research Related to Underlying Neurological Mechanisms

Research into the physiological mechanisms that underlie sensory modulation disorder (SMD) has taken various forms. Each approach is based on Ayres' original theories. The **autonomic nervous system** (ANS) was first targeted because arousal mechanisms often appear disrupted in children with SMD. Brain mechanisms responsible for automatically filtering out redundant or unnecessary stimuli from the environment have also been targeted using high density electrophysiology recordings during a sensory gating paradigm. Because SMD is a hypothesized disruption in "sensory integration," neuroscience techniques that study MSI have also been investigated. What follows is a summary of each line of research.

Studies of the Autonomic Nervous System

Studies related to the role of the ANS in SMD are based on the observation that children with sensory over-responsivity (SOR) display fight-or-flight behaviors in response to adverse sensory experiences and have difficulty regulating their recovery from a perceived sensory challenge (Miller, Anzalone, Lane, Cermak, & Osten, 2007). The ANS regulates activity through the sympathetic and parasympathetic branches, which are responsible for our ability to adapt internal processes in response to ongoing changes in the environment. The sympathetic branch is most often referred to as a quick, mobilizing system that controls our fight-or-flight response; changes in sympathetic activity are often measured using **electrodermal response,** or EDR, parameters. The parasympathetic system is a slow, dampening system that helps maintain or regain homeostasis and self-regulation; changes in parasympathetic activity are reflected in **heart rate variability, respiratory sinus arrhythmia** (RSA), or **vagal tone.** The two branches work together to control internal functions related to sensory, motor, visceral, and neuro-endocrine functions (refer to Chapter 4, Structure and Function of the Sensory Systems, Fig. 4-4).

Since 1995, Miller and colleagues have had a program of research examining ANS regulation in response to sensory stimulation in children with SMD. Since initiating this program, and in part supported by the Wallace Research Foundation as well as through a federal grant obtained by Miller, several other labs around the country have become engaged in physiological data collection (Lane and colleagues; Schaaf and colleagues; Parham and colleagues).

Results from several studies showed that children with SOR demonstrated elevated EDR (Mangeot et al., 2001; Schoen, Miller, Brett-Green, & Nielsen, 2009) and slower habituation to repeated sensory stimuli using a paradigm known as the **Sensory Challenge Protocol** (SCP) (McIntosh, Miller, Shyu, & Dunn, 1999). Figure 16-2 shows manual application of sensory stimuli during the SCP; electrodes are attached to the child in order to measure physiological responses to the stimuli during multiple trials. This research suggested that children with SOR have sympathetic over-activity in comparison with typically developing children and compared with children with autism (Schoen et al., 2009). There was also a significant association between children's physiological responses and their functional behavior scores based on parent report as measured by the Short Sensory Profile (Mangeot et al., 2001; McIntosh et al., 1999; Miller, McIntosh, Shyu, & Hagerman, 1999). Similarly, adults with SOR demonstrated a significantly elevated initial skin conductance response compared with controls, when presented with a loud sound through headphones (Brown, Tollefson, Dunn, Cromwell, & Filion, 2001). Collectively, these studies demonstrate that physiological measures can differentiate individuals with and without SOR.

FIGURE 16-2 The Sensory Challenge Protocol was administered in a room decorated to resemble a spaceship. Children were presented with a sensory stimulus repeated eight times, in each of six sensory domains. Data were collected on sympathetic, parasympathetic, or stress responses to the stimuli over time.

Because regulation of an individual's reactivity involves a balance of activity within both the sympathetic and parasympathetic divisions of the autonomic nervous system, Schaaf and colleagues (2003) examined the parasympathetic nervous system response across the SCP using vagal tone as the index of parasympathetic activity. Children with SMD had significantly lower vagal tone compared with typically developing children, suggesting less effective parasympathetic functioning. Subsequent investigation examined vagal tone within each domain of the SCP and found a nonsignificant trend ($p = 0.083$) for baseline vagal tone to be lower in children with SMD than in typically developing controls (Schaaf et al., 2010). However, in this study children with SMD reacted with increased, rather than decreased, vagal tone to cope with the stimuli. Only vagal tone at baseline was lower and appeared to be associated with the severity of SMD based on Short Sensory Profile scores. In addition, the children with severe SMD also had significantly lower scores on Communication, Daily Living, and Adaptive Behavior Composite scores of the Vineland Adaptive Behavior Scales compared with typical children (Schaaf et al., 2010).

Together, these findings suggest that children with SMD show atypical parasympathetic regulation, which may influence their ability to self-regulate and cope with environmental stimuli. Further, these children may have different physiological-behavioral relationships than typical children. An under-reactive parasympathetic system in children with SMD may not be able to provide the support needed for normal physiological regulation during daily life activities. Adequate regulation of parasympathetic activity provides a basis for behavioral flexibility and adaptation needed to cope with the various changing inputs in one's daily environment and thus the ability to successfully engage in normal routines and activities of daily life.

Neuroimaging

Neuroimaging technology has evolved such that it can be used as a quantitative measure of neural activity that can help expand our knowledge of the relationship between physiological processing and behavioral manifestations. Many modalities can be used to assess functional brain imaging, including **evoked response potential** (ERP), **electroencephalogram** (EEG), **functional magnetic resonance imaging** (fMRI), **positron emission tomography** (PET), and **magnetoencephalography** (MEG) and **diffusion tensor imaging** (DTI; an alternative method of magnetic resonance imaging).

Sensory Gating Studies and ERP Studies

The inability to filter out unnecessary stimuli from the environment, also known as sensory gating, is one characteristic of SOR described by Ayres (Ayres, 1972; Davies & Gavin, 2007). Thus, sensory gating paradigms have been used to investigate the neurophysiology of sensory processing in many disorders including schizophrenia, attention deficit-hyperactivity disorder (ADHD), and traumatic brain injury.

Sensory gating paradigms typically involve measuring the amplitude of particular ERP components as a function of the relative "salience," or potential importance, of a stimulus: as salience goes down, ERP amplitude goes down, reflecting reduced neural processing of relatively unimportant stimuli. ERP data is collected using EEG technology in which surface electrodes are placed on a person's scalp, and sometimes the face, to measure electrical activity in the brain (Fig. 16-3). In sensory gating studies, salience is operationalized as novelty by presenting stimuli in pairs: the first ("conditioning") stimulus of the pair is relatively novel and thus of higher salience than the second ("test") stimulus of the pair. The efficiency with which the brain "gates out" the second stimulus of the pair is typically quantified by comparing ERP amplitude evoked by the second stimulus to ERP amplitude evoked by the first stimulus of the pair (Fig. 16-4).

FIGURE 16-3 EEG cap worn by children to obtain data about underlying mechanisms related to multisensory integration.

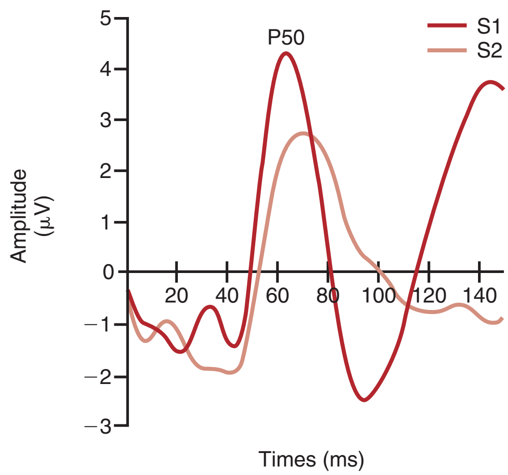

FIGURE 16-4 Sensory gating is measured using the P50 EEG peak. P50 is the most positive peak following a stimulus. S1, the red line, shows the initial response to the stimulus. S2, the pink line, shows the reduced response to the second stimulus and reflects filtering or gating of the CNS response to redundancy of input and a lack of salience.

Examining adults with self-reported sensory sensitivity (Adult Sensory Profile; Brown & Dunn, 2002), Kisley and colleagues found that greater SOR correlated with less efficient sensory gating (Kisley, Noecker, & Guinther, 2004). This finding supports the hypothesis that individuals with substantial SOR over-process stimuli of low salience.

In a similar study of children from 5 to 12 years of age identified as having SMD (predominantly the SOR subtype), Davies and Gavin (2007) demonstrated significantly less sensory gating than was found in typically developing control children, indicating that children with SMD had diminished ability to filter out repeated auditory input. A significant relationship between sensory gating and age was found only in children who were typically developing, not in children with SMD; this further suggests that deficits in sensory gating do not simply go away through time or because of maturation alone in children with SMD. Further, the study paradigm correctly classified children with SMD vs. typically developing children with 86% accuracy, and the prediction equation was sensitive in discriminating the SOR subtype. Collectively, these findings suggest that there is a maturational course of sensory gating in typical children that is not apparent in children with SMD.

Expanding on these findings, Davies and colleagues used ERPs to investigate sensory registration of different intensities and frequencies of auditory stimuli. Using this paradigm, children with SMD were correctly classified with 90.5% accuracy (Davies, Chang, & Gavin, 2009). Consistent with these findings, investigators correctly classified children with SMD with 79% accuracy in a follow-up study that used the same sensory registration paradigm (Gavin et al., 2011). Both studies showed atypical neural processing of auditory stimuli, particularly in a late component of the ERP reflective of increased cognitive activity involved in processing (Polich, 2007), suggesting that children with SMD fail to selectively regulate their sensitivity to auditory stimuli of differing frequencies and intensities.

Multisensory Integration Studies

A disorder in MSI was first hypothesized by Ayres as the underlying impairment in children with sensory processing and integration challenges (Ayres, 1972). Additionally, clinical observations of children identified with the SOR subtype of SMD demonstrate that they are overwhelmed in situations where sensations from multiple modalities are present (e.g., a busy mall or a school cafeteria). EEG has been used to study the underlying mechanisms related to MSI.

Children with SOR have been shown to have weaker overall ERPs to auditory and somatosensory stimuli individually than their typically developing peers (Brett-Green, Miller, Schoen, & Nielsen, 2010). Of interest, the early auditory-somatosensory integration that occurs in typically developing children (Brett-Green, Miller, Gavin, & Davies, 2008) and adults (Foxe et al., 2000; Murray et al., 2005; Touge et al., 2008) has been shown to be different in children with SOR (Brett-Green et al., 2010). In typical children, auditory-somatosensory integration occurs early in sensory information processing, and in lower level cortical regions. However, the processing pattern in children with SOR reflects higher level frontal MSI, which may redirect attention to the stimuli and explain why these children attend to all environmental stimuli.

These studies provide preliminary support for the hypothesis that the behavioral over-responsivity to auditory and somatosensory stimulation and the seeming inability to integrate multisensory input that is characteristic of children with SOR may have a neural basis. Atypical MSI may contribute to the challenges experienced by children with SOR during daily life that prevents successful interactions at home, school, and community environments. Additional MSI studies are needed to replicate and expand these findings.

Functional connectivity is a term that is commonly used to denote statistical associations between remote brain regions (Friston, 2011). It is reflected through **fMRI** by looking at changes in blood flow, metabolic uptake using PET, or electromagnetic fields related to neuronal activity, as is done in MEG. Functional connectivity can be assessed at rest or during activation. For individuals who are having clinical difficulties, such as those with sensory integrative disorders, neurophysiological disruption may occur in the primary or secondary processing cortex (local) or in the transmission of information between relevant cortices (long-range).

Researchers at the University of California, San Francisco, and their colleagues are currently using MEG and DTI to investigate sensory processing in typical children, children with sensory modulation challenges, and children with autism spectrum disorders (Chang et al., 2014; Owen et al., 2013; Chang et al., 2016). This technology is particularly useful in determining which brain regions might be working together in response to sensory events and how they are functionally connected.

Examining the underlying neural mechanisms of SMD by exploring the role of white matter using DTI, Owen and colleagues (2013) found reduced white matter microstructure in primary sensory tracts (parietal and occipital) and pathways where MSI takes place. These findings differentiate children with SMD from children with ASD and ADHD, where abnormalities in DTI have been identified in frontal and temporal regions (Tamm, Barnea-Goraly, & Reiss, 2012; Travers et al., 2012). In addition, investigators found an association between reduced white matter microstructural integrity and atypical sensory behavior (Owen et al., 2013) as reflected on the Sensory Profile (Dunn, 1999), suggesting a specific biomarker for SMD, which appears to be distinct from other clinical diagnosis. A subsequent study by this same group of investigators (Chang et al., 2014) compared the white matter microstructure found in children with SMD to children with ASD. Similarities between the groups were found with alterations in parieto-occipital tracts, which subserve auditory, tactile, and visual perception and integration. Interestingly, the alterations were somewhat more pronounced for children with SMD, perhaps reflecting the primary feature of inadequate modulation in this group. Nonetheless, the inadequate

HERE'S THE EVIDENCE

DTI is a type of MRI that measures microscopic movement of water in the brain as a way to evaluate the integrity of the white matter connectivity. In this study by Chang and colleagues, DTI fiber tractography was used to evaluate the structural connectivity of specific white matter tracts in boys with autism spectrum disorder (ASD) (n = 15), sensory processing disorder (SPD) (n = 16), and typical boys (n = 23). In boys with SPD and ASD, decreased connectivity was found in parieto-occipital tracts involved in sensory perception and multisensory integration. Specific parieto-occipital white matter tracts identified as having decreased connectivity relative to controls included the dorsal visual stream and posterior corona radiate (both ASD and SPD), as well as the splenium of the corpus callosum (SPD only). The ASD group alone showed decreased connectivity in temporal tracts thought to be associated with social-emotional processing. Specific connection deficits were noted between the fusiform and the amygdala, the fusiform and the hippocampus, and within the inferior longitudinal fasciculus. Correlational analyses identified significant associations between impaired white matter connectivity and auditory processing, working memory, social skills, and inattention. Overall, the results identify an underlying neurological basis for sensory processing disorders and help identify specific circuits that may differentially diagnose ASD and SPD.

Chang, Y., Owen, J. P., Desai, S. S., Hill, S. S., Arnett, A. B., Harris, J., . . . Mukherjee, P. (2014). Autism and sensory processing disorders: Shared white matter disruption in sensory pathways but divergent connectivity in social-emotional pathways. *PLOS One, 9*(7), e103038.

PRACTICE WISDOM

Although most occupational therapy clinicians working with children with sensory integrative and processing disorders are not going to be using techniques discussed in this chapter such as DTI, fMRI, and EEG, the research is still relevant. Clinicians are often asked "Why is my child this way?" or "Why can't my child do things as easily as other children?" The research discussed in this chapter suggests that the brains of children with sensory integrative and processing disorders are wired differently—that in some children, responses are less inhibited, whereas in others, parts of the brain are just not communicating as effectively or as efficiently as necessary for optimum performance. However, the good news that clinicians can give to families is that we know the brain is capable of change. With therapeutic intervention, connections in the brain can be strengthened and different parts of the brain can begin to work more in sync with each other. As research in the field of sensory integration and processing continues to advance, it is likely the same technologies used in this chapter for differential diagnosis and descriptive research will be used to measure the effectiveness of intervention—providing therapists with a solid evidence base for the treatment of children with sensory integrative disorders.

sensory modulation was linked with atypical conductivity between regions of the brain that process single modality input and those regions responsible for MSI in both groups of children. Children with SMD also showed signs of poor interhemispheral transfer of information, something children with ASD did not show. A clear difference emerged; children with ASD showed reduced connectivity in regions that facilitate emotional processing, whereas children with SMD did not.

HERE'S THE POINT

- Individuals with SMD have atypical sympathetic reactivity and parasympathetic regulation compared with individuals without SMD.
- Individuals with SOR have impaired sensory gating, which does not appear to go away with age.
- SMD has been linked with atypical connectivity and conductivity between areas of the brain associated with sensory processing and integration.

Animal Research: From Cages to Clinics

In the study of sensory integrative disorders and sensory integration treatment, there are multiple levels of analysis to consider and whether or not to use animal subjects decidedly comes from the established research question. If the research question pertains to the behavior of the organism (e.g., human), then the logical choice is to study that organism. If, however, the research question pertains to the cellular or molecular mechanisms, which underlie atypical sensory processing, or the effect sensory integration treatment has on neuronal morphology in the developing brain, then these types of analyses may be best studied in non-human species. For example, despite normal hearing capabilities, deficits in the ability to appropriately respond to sounds in the environment are seen in 50% to 75% of children with ASD (Hitoglou, Ververi, Antoniadis, & Zafeiriou, 2010; Kientz & Dunn, 1997). This under-responsivity to auditory stimuli has been shown to impact cognitive and academic performance and social functioning in this population (Ashburner, Ziviani, & Rodger, 2008; Liss et al., 2006). Using a rodent model, Reynolds and colleagues (2012) demonstrated that auditory under-responsivity can be elicited by **teratogenic insult** during a time period equivalent to the human third trimester, leading to altered neural connectivity and morphological changes in the subcortical auditory system. Targeted pharmacological and sensory-motor interventions that enhance neural plasticity can therefore be tested in the rodent model to examine their effectiveness in ameliorating auditory response deficits and remedying deficits in neural morphology. Effective strategies and knowledge gained from this animal research can contribute to a continuum of research that has the potential to lead to effective strategies for reducing auditory processing deficits in children with ASD. In this way, animal research can provide unique insight into sensory processing (theory, treatment, and disorders) that cannot be gained from human studies alone.

The importance of animal research to public health cannot be overstated; nearly every medical breakthrough in the last century has used animals in some way. Animals typically used in basic science research, such as rodents (i.e., rats and mice), are not as dissimilar from humans as one would typically think; similar neurological structures and physiological processes exist between species because of common evolutionary origins. This provides researchers with an opportunity to use non-human models to study causal relationships between disorders of sensory processing and treatment outcomes resulting from sensory-based interventions.

Life Span Studies

A key rationale for using animals in research is their accelerated life span. The accelerated pattern of development seen in many animal species provides an opportunity for researchers to study the long-term effects of early life experiences in humans, to study the retention of traits through multiple generations, or to look at the effects of diseases or treatment through time, which is particularly difficult to do in humans. One example of how this type of research has contributed to sensory integration theory and practice is the work of Michael Meaney and colleagues (for review, see Meaney, 2010).

As early as the 1960s, researchers found that, as adults, animals exposed to brief periods of handling (i.e., being picked up and manipulated in some way by examiners) during the first weeks of life showed reduced responses to stress compared with non-handled animals. Meaney's work has focused on explaining this phenomenon and studying how variations in maternal care regulate the development of the stress response during the life span (Meaney, 2010). One key finding was that the effects seen in those earlier studies were not caused by the handling itself, but rather that when the pup was returned to the home cage, the mother rat would initiate high rates of licking and grooming: strong tactile input. Interestingly, it was this tactile input early in life that appeared to cause long-lasting changes in the rat's ability to respond to stressors.

Meaney's group took their work a step further to examine natural variations in maternal care and found similar results. Pups that were licked more grew to be less fearful and produce fewer stress hormones than pups that were licked much less. The results were the same even when the mother's licking was replaced with an artificial tactile stimulus, a research assistant stroking the pup using a soft paintbrush (Caldji et al., 1998; Hellstrom, Dhir, Diorio, & Meaney, 2012; Menard, Champagne, & Meaney, 2004; Weaver et al., 2004). In addition to behavioral and hormonal changes, structural neurological differences between high-groomed and low-groomed rats were found as well. Rats who received high levels of tactile input had more cortisol receptors in their brains (Liu et al., 1997); the greater number of receptors relates to an enhanced capacity of the brain to turn off or tone down the stress response using the negative feedback loop of the **hypothalamic–pituitary–adrenal** (HPA) axis system. Therefore, through a series of eloquently and systematically designed animal studies, Meaney's group was able to link a sensory feature (tactile stimulation early in life) to an observed behavioral outcome (modification of fear response), to a measurable hormonal outcome (reduction in cortisol), and finally to a neurobiological feature (greater number of cortisol receptors).

The experimental design and life span approach used in these studies allowed Meaney and colleagues to support the premise that positive tactile stimulation provided in early infancy has the potential to organize the central nervous system (CNS) in a way that modifies neurological stress responses throughout the life span. These principles relate directly to the use of tactile stimuli in sensory-based treatments, including protocols such as infant massage (Smith, 2012) and therapeutic brushing (Kimball et al., 2007).

Impact of Treatment

Animal models have also been used to explore aspects of treatment. Specifically, the impact of sensory-motor interventions on autism-related behaviors has been studied using **environmental enrichment** paradigms.

Environmental enrichment involves changes to an animal's home cage or secondary exploratory area that provide enhanced sensory, motor, cognitive, and potentially social opportunities. These enhancements are relative to standard housing conditions, which generally entail a cage or pen with bedding and access to food and water (Nithianantharajah & Hannan, 2006). Figure 16-5 shows an example of an enriched housing

FIGURE 16-5 Enriched housing conditions provide enhanced sensory, motor, cognitive, and potentially social opportunities to the animals compared with standard housing conditions. These enhancements parallel the types of novel opportunities therapists often try to provide in the context of sensory integration therapy.

condition for rodents. An enriched environment is often a large space (relative to the home cage) that allows exploration and the introduction of a variety of objects. These objects, varying in shape, size, weight, smell, and texture, may include tubes, balance platforms, climbing apparatuses, balls, or running wheels, which are generally changed out or manipulated in some way on a scheduled basis to maintain the concept of novelty and complexity in the environment (Reynolds, Lane, & Richards, 2010). These features of environmental enrichment align with the core principles of sensory integration treatment (Table 16-2), specifically the importance of providing multiple sensory opportunities or stimuli, providing increasing challenges, offering freedom to explore and choose activities, providing equipment, and arranging the room to facilitate engagement (Parham et al., 2007, 2011). In both environmental enrichment and sensory integration interventions, the changes noted following treatment are often described as *experience dependent,* indicating that they result from active interaction between the subject and the affordances available in the environment.

Mouse strains that are inbred to display autistic-like traits have been used to study the effects of various interventions, including environmental enrichment. The BTBR T+ tf/J or "BTBR" mouse is one such strain that displays impaired social behaviors, atypical repetitive behaviors (i.e., rigid over-grooming), and learning impairments.

TABLE 16-2 Comparison of Essential Features of SI and Enriched Environment Models

ESSENTIAL FEATURES	ENRICHED ENVIRONMENTS	SI INTERVENTION
Sensory experiences	Large cage to explore; equipment to climb, balance, smell, touch, and push	Large therapy space with points of suspension for swings. Ramps, tunnels, balls, cushions, and climbing and jumping devices
Structural features	Adequate space and multisensory equipment must be present and available during "treatment" condition	Adequate space and multisensory equipment is necessary. Also, therapist must be present and have adequate training and qualifications.
Novelty	Experimenter changes the material presented in the cage on a scheduled basis.	Variety of materials available. Therapist's role is to facilitate more challenging or imaginative play activities and change materials as deemed appropriate on a child-by-child and session-by-session basis.
Challenge	Complexity of environment provides opportunities for more complex motor patterns and integrative experiences.	The environment itself should afford sensory-motor challenges, but it is the role of the therapist to facilitate the "just right challenge."
Active engagement	To benefit from the enriched environment, animals must actively engage with the materials in the environment.	Child collaborates with therapists on activity choice and is actively engaged in planning and executing sensory and motor activities.
Play and enjoyment	Sensory and motor experiences are generally enjoyable and encourage engagement (sensory stimuli presented is not noxious or aversive).	Therapist creates a context of play and facilitates child's own social, motor, imaginative, or object play.
Social	Sometimes multiple animals are introduced to the enriched environment simultaneously to facilitate social interaction.	Primary social relationship is between therapist and child. Social interaction between children may occur, but this is not identified as a core element of SI treatment.
Safety	When social interactions occur, generally animals are of the same size, and "bully" animals are not introduced into the cage.	Therapist ensures physical safety through placement of equipment and maintaining proximity to child. Emotional safety in the form of sustaining optimal levels of arousal.

Note: Originally published in the *Journal of Neurodevelopmental Disorders* (Reynolds, Lane, & Richards, 2010); original publisher BioMed Central (London, United Kingdom).

MacPherson and colleagues (2008) examined the effect of continuous environmental enrichment presented in the animal's home cage for 8 days before memory training tasks. Results of this study revealed that even brief periods of enrichment may improve object recognition memory in these BTBR mice. Yang and colleagues (2011) used a social enrichment paradigm, demonstrating that socially housed BTBR mice show significant improvements in social approach behaviors as young adults. More recently, Reynolds and colleagues (2013) examined the effectiveness of environmental enrichment (classic paradigm with novel sensory-motor opportunities) on the reduction of repetitive behaviors in the BTBR mice. Behaviors were captured by examining both the time and sequence of grooming. After 30 days of enrichment housing, BTBR mice demonstrated a significant reduction in time spent grooming relative to BTBR mice in standard housing; however, no changes were noted in the rigidity of their grooming sequence. These authors concluded that environmental enrichment may be beneficial for reducing the time spent engaging in repetitive behaviors, but it may not change the overall quality of the behaviors when they do manifest.

These studies, using the autistic-like inbred strain, suggest that engagement in an opportunity-rich environment with novel sensory, motor, and social challenges may alter core autism-related behaviors such as social deficits and repetitive behaviors, as well as positively influence learning and memory. Based on the overlapping core features of enriched environments and sensory integration treatment, we can deduce that sensory integration treatment would lead to positive outcomes for children with autism as well. The challenge is to design rigorous translational research studies that investigate this possibility.

The effect of enriched environments has also been studied in an animal model of fragile X syndrome, because the symptoms of fragile X syndrome include hyperactivity, anxiety, hypersensitivity, spatial processing deficits, and altered sensory-motor gating. Restivo and colleagues (2005) demonstrated that engagement in enriched environments largely reduced anxiety and restored habituation (memory function) in the fragile X mouse. Interestingly, enrichment also reversed morphological deficits associated with the fragile X mice, with enrichment increasing branching, length, spine density, and maturity of dendrites (Restivo et al., 2005). As with the previous discussion of autistic-like mice, this study using an animal model of fragile X syndrome suggests that engagement in an opportunity-rich environment, with novel sensory and motor challenges, may influence behaviors often seen in children with sensory-processing deficits including anxiety and deficits in learning and memory. Further, this work supports the premise that sensory-motor interventions have a direct influence on neurological systems and structures via mechanisms of experience-dependent neuroplasticity.

Environmental Influences and Epigenetic Mechanisms

Although many of the disorders in which we see behaviors associated with sensory processing challenges are known to be highly heritable (e.g., ADHD, ASDs), study of the genetic sequence (or abnormalities in the genome) alone is likely insufficient for fully understanding the complex and heterogeneous phenotype of children with developmental disorders (Rangasamy, D'Mello, & Narayanan, 2013). **Epigenetics** is the study of changes in behavior or appearance caused by mechanisms other than changes in the underlying DNA sequence; the term "epi-" is derived from Greek, meaning "over" or "above," so *epigenetics* refers to processes occurring above or around the genes. This means that different environmental influences such as nutrition, exposure to drugs, or (in the case of Meaney's work) tactile stimulation can all affect gene expression without changing the genetic sequence (Meaney, 2010).

Four decades ago, Ayres (1979) identified the importance of environmental influences on the genome, hypothesizing that "Genetic factors in certain children may make one part of the brain more vulnerable than usual. In this highly vulnerable state, environmental toxins may interfere with sensory integrative development" (p. 54). The work of Schneider and colleagues exemplifies how animal research can be used to test Ayres' hypothesis, uniquely contributing to our understanding of how prenatal and early postnatal environmental factors influence the development of sensory modulation challenges (Moore et al., 2008; Schneider et al., 2007, 2008, 2009; Schneider, Moore, & Adkins, 2011). Using a non-human primate model, rhesus monkeys (Macaca mulatta), these researchers examined causal effects of prenatal alcohol and prenatal stress exposure on the development of tactile defensiveness (also known as tactile over-responsivity or hypersensitivity). As noted by Schneider and colleagues (2011), use of monkeys, as opposed to rodents, provides the benefit of shared gestational characteristics with humans, such as a longer gestation, slow fetal growth, and single birth. Nonhuman primate research is important in that it bridges the gap between experimental rodent research and clinical human research. As part of a 20-year prospective longitudinal program of research, 85 rhesus monkeys were derived from one of four conditions: (1) prenatal stress exposure, in which mothers were removed from home cages daily and exposed to a noise stressor for 75 days out of a 165-day gestation period; (2) prenatal alcohol exposure, in which pregnant females voluntarily consumed 0.6 g/kg alcohol daily throughout gestation or during specific gestational periods; (3) both prenatal stress and alcohol exposure; or (4) control group. The offspring were followed from birth to old age.

All offspring were assessed for sensory processing function twice: during the neonatal period and again during early adulthood. As neonates, they were tested on a battery that included tactile and vestibular items (Fig. 16-6a and 16-6b) (see Schneider et al., 2017 for details). During early adulthood, when the offspring were 5 to 7 years of age, they were tested using the Sensory Processing Scale for Monkeys (SPS-M), an evaluation procedure developed by these investigators and modeled after methods used to test sensory processing abilities in children (Baranek & Berkson, 1994; Miller et al., 1999). During the SPS-M, examiners exposed offspring to three different tactile stimuli (feather, cotton ball, stiff craft brush), six trials each; animal behaviors were coded in response to each stimulus on a scale ranging from 0 to 3, meaning "no withdrawal" to "extreme withdrawal" (Schneider et al., 2008). In addition to behavioral indices recorded during the SPS-M, PET neuroimaging was used to examine whether the pattern of responses to repeated tactile stimulation was associated with **dopamine** function in the **striatum.**

Results indicated that the young adult control animals showed an expected pattern of habituation to tactile stimuli, as evidenced by a gradually decreasing amplitude of withdrawal responses across the six trials. Monkeys in the prenatally stressed group, conversely, showed a pattern of sensitization in which the amplitude of withdrawal responses increased during the six trials. Moreover, prenatal alcohol exposure led to a higher overall magnitude of withdrawal response across trials without a clear pattern of habituation or sensitization (Schneider et al., 2007).

In addition, genetic variations were found between monkeys with and without tactile over-responsivity. Specifically, animals with tactile over-responsivity had the short (S) variant, or allele, of the gene known to regulate transport of the neurotransmitter serotonin in the brain. This gene is closely related to stress responsivity and other neurobiological functions, and it is analogous to the human serotonin transporter length variant. The short (S) allele is known to be less efficient than the long allele at gene

A B

FIGURE 16-6 Assessment of neonatal monkey for sensory processing function. In photo A, one aspect of vestibular function is being assessed, looking at the ability to maintain body extension while suspended in prone. In photo B, the neonate is being stroked gently on the hand to test the tactile system.

transcription and is associated with heightened biological sensitivity to context and more vulnerability to negative events (Ellis & Boyce, 2011). Serotonin regulates several developmental functions involved in neural circuit formation, and it plays a crucial role in modulating developmental plasticity during critical periods of development. Serotonin neurons project diffusely to a wide range of brain regions involved in sleep, pain, sensory function, endocrine function, and integration of emotional, cognitive, and motor function (Lesch et al., 1997).

Another finding from this research was that tactile over-responsivity and decreased habituation on the SPS-M were associated with altered striatal dopamine (DA) function. There are five mammalian DA receptors (designated D1, D2, D3, D4, and D5), with D1 and D2 receptors having important motor and reward functions, including attention, working memory, and executive function (Arnsten, 2013). PET measures of striatal dopamine D2 receptor availability were found to correlate negatively with habituation to repeated tactile stimulation and positively to the magnitude of tactile responsivity (Schneider et al., 2008). Moreover, striatal dopamine transporter binding was also negatively correlated with habituation and positively correlated with tactile responsivity (Converse et al., 2013). This is interpreted to suggest that altered functioning of the dopaminergic neuro-modulatory circuits may underlie the phenotypic expression of tactile over-responsivity.

A final finding from Schneider's work is that tactile over-responsivity showed moderate continuity from the neonatal period into adulthood (Schneider et al., 2017). Developmental continuity is important because psychological functions that show continuity have greater potential to induce maladaptation later in life. Continuity also raises the importance of early intervention for prevention of later problems.

Taken together, these results provide causal evidence to support Ayres' hypothesis that environmental influences may interact with genetic expression to elicit phenotypic behaviors associated with sensory modulation disorder. Further, alterations in the serotonin and dopamine systems may be factors influencing the processing of sensory input, which could be targets for intervention or used as outcome measures in future studies.

Drawing from Animal Research

Extracting information about sensory processing and sensory integration treatment effectiveness from animal studies must be done with caution. Using animal models to inform human practice is limited by the fact that the neurological systems of animals (particularly rats and mice) are much less complex than those of humans. It is also known that genes can express themselves differently in different species, so even sophisticated genetically engineered animal models may not produce disorders or behaviors relevant to the human population. Further, although behavioral assays have been developed to measure behavior in animals, these can only be approximations of human behavior; there really is no way to know for sure whether an animal is feeling anxious or stressed. These limitations must be taken into consideration and balanced out with the advantages and opportunities that animal research provides. Sensory integration researchers and practitioners have made theoretical links between the brain and behavior for a long time. In order to fully understand the mechanisms underlying these behaviors, a translational and systematic approach will likely be essential, with researchers and clinicians communicating and contributing across all levels of science.

HERE'S THE POINT

- Research with rodents supports the importance of tactile stimulation early in life as a means of developing healthy neurological responses to stress.
- Interaction in enriched sensory and motor environments can reduce autism-related behaviors in animal models and lead to lasting changes in the brain.
- Adverse prenatal or early life events (e.g., drug, alcohol, or stress exposure) may increase the risk for SMD.

Studies of SMD in Populations Comorbid for Other Conditions

A high incidence of SMD is reported in clinical samples, most notably in children with developmental disabilities, ADHD, and ASD. Prevalence estimates across these groups range from 30% to 90%. In individuals with diagnosed developmental disabilities, the rate of comorbid SMD is estimated to be 30% to 85% (Baranek, 2002; Leekam, Nieto, Libby, Wing, & Gould, 2007), depending on the specific developmental diagnosis. For example, for children with ASD, the rates have been estimated to be between 69% and 90% (Baker, Lane, Angley, & Young, 2008; Baranek, David, Poe, Stone, & Watson, 2006; Ben-Sasson et al., 2007; Leekam et al., 2007; Liss et al., 2006; Rogers, Hepburn, & Wehner, 2003; Tomchek & Dunn, 2007). Some studies that found significant SOR in children with autism or Asperger syndrome compared with typical controls highlighted symptoms in the auditory, taste or smell, and tactile domains (Adamson, O'Hare, & Graham, 2006; Ashburner et al., 2008; Baker et al., 2008; Kern et al., 2006; Rogers et al., 2003; Talay-Ongan & Wood, 2000). Others have found a higher incidence of sensory under-responsiveness (SUR) (Ben-Sasson et al., 2007; Rogers & Ozonoff, 2005), particularly in the auditory domain, as reflected by the failure to respond to one's name (Baranek, Boyd, Poe, David, & Watson, 2007; Osterling, Dawson, & Munson, 2002; Werner, Dawson, Osterling, & Dinno, 2000). Because of this growing body of literature, the latest edition of the *Diagnostic and Statistical Manual of Mental Disorders,* Fifth Edition (*DSM-5;* American Psychiatric Association, 2013), includes sensory dysfunction as a criterion for the diagnosis of ASD, specifically those with hyper- or hyporeactivity. Although prevalence studies of sensory dysfunction have not been conducted in children with ADHD, the literature describes frequent characterization of sensory processing challenges in this clinical group (Ghanizadeh, 2011). An examination of sensory symptoms based on referrals to research studies indicates that 54% to 69% of the children with ADHD have comorbid sensory modulation challenges, particularly the SOR subtype (Lane, Reynolds, & Thacker, 2010; Parush, Sohmer, Steinberg, & Kaitz, 2007; Reynolds, Lane, & Gennings, 2009). Additional diagnostic groups identified with sensory processing impairments include obsessive-compulsive disorder, fragile X syndrome, and mood disorders (Baranek, 2002; Brown & Dunn, 2002; Liss et al., 2006; Mangeot et al., 2001; Miller et al., 1999; Parush et al., 2007; Rich, Vinton, Grillon, Bhangoo, & Leibenluft, 2005; Rogers & Ozonoff, 2005).

SMD has also been characterized in adult populations with **comorbid** psychiatric disorders. Rosenthal, Ahn, and Geiger (2011) examined sensory modulation in a group of adults with borderline personality disorder (BPD). Sixty-seven adults participated in this study: 30 of these adults met full diagnostic criteria for BPD and 37 were healthy controls. All participants completed an unstructured interview assessing sensory symptoms across five sensory domains (i.e., auditory, visual, touch, taste, and smell) during adulthood. Results indicated that, averaged across all sensory domains, individuals with BPD report higher levels of responsivity than typical controls. In addition, individuals with BPD also report higher responsivity to each specific sensory domain, especially in the auditory domain. These findings suggest that emotional responsivity in BPD may be associated with a heightened responsivity to specific kinds of sensory stimuli. Other research on adults suggests that adults with bipolar disorder and schizophrenia also show characteristics of SMD (Brown, Cromwell, Filion, Dunn, & Tollefson, 2002; Perry, Minassian, Feifel, & Braff, 2001).

Sources of Evidence: Physiological and Behavioral

There are multiple sources of evidence showing behavioral and physiological differences in sensory processing and integration in children within other clinical groups. Similar to studies that have focused on children with SMD, these studies have examined electrophysiological parameters and cortisol stress responses. In addition, links with anxiety have been investigated.

Electrophysiology

One source of evidence of physiological difference in children with ADHD comes from electrophysiological recordings of the **somatosensory evoked potential** (SEP), a measure of neural responsiveness to somatosensory stimulation. Parush and colleagues (2007) found differences in SEP recordings related to activity at the level of the spinal cord and in the somatosensory cortex, between boys with ADHD plus tactile over-responsivity, boys with ADHD in the absence of tactile over-responsivity, and boys developing typically. These results suggest that tactile over-responsivity may be related to abnormal central neural responses to a somatosensory stimulus.

Autonomic Nervous System

As reported earlier, sympathetic nervous system activity as measured during the SCP has characterized children with SMD as different from typically developing peers. There is also a growing body of literature showing differences between children with SMD and those with other established diagnostic categories such as fragile X syndrome, ADHD, and autism (Schoen et al., 2009). In particular, the behavioral problems of hyperarousal, hyperactivity, aggression, and anxiety noted in individuals with fragile X syndrome are thought to be related to strong reactions to auditory, tactile, visual, and olfactory stimuli (Hagerman, 1996; Hagerman & Cronister, 1996). Sensory reactivity is suggested to underlie the approach or withdrawal behaviors seen in fragile X syndrome (Cohen, 1995; Cohen et al., 1991). In a study by Miller and colleagues (1999), individuals with fragile X syndrome had significantly stronger reactions to auditory, tactile, visual, and olfactory stimuli than typically developing controls. In individuals with fragile X syndrome, patterns of EDR to stimulation in one sensory modality predicted the patterns of EDRs in four other sensory systems (Miller et al., 1999). Because electrodermal activity (EDA) indexes sympathetic nervous system activity, these data suggest that overarousal to sensation may underlie some of the symptomatology of fragile X syndrome (Miller et al., 1999).

The physiology of children with ADHD has also been studied using the SCP. Compared with children with ADHD, children with just SOR exhibited larger magnitude responses to all stimuli and did not habituate to recurring sensory stimulation (McIntosh et al., 1999), which differentiated them from children with ADHD who displayed atypically large reactions to the initial presentation of a sensory stimulus, but habituated following subsequent presentations of the stimuli (Mangeot et al., 2001). Lane, Reynolds, and Thacker (2010) had also identified SOR in a subgroup of children with ADHD, finding that children with both ADHD and SOR had more difficulty recovering from the SCP than did either typical children or children with ADHD and no SOR.

Miller and colleagues (2012) more specifically evaluated specific differences between ADHD and SMD by separately classifying those children with a comorbid diagnosis of ADHD plus SMD (based on global clinical impression) into one group and comparing this dual diagnosis group with children with either ADHD alone, SMD alone, or typically developing children. Physiological differences during the SCP were confirmed; children with SMD alone exhibited responses of a significantly greater magnitude to stimuli compared with either children with ADHD alone or typically developing children. However, the responses of children with only ADHD did not significantly differ from those of typically developing children (Miller et al., 2001). In the earlier study, there was a large degree of variability in the ADHD sample (Mangeot et al., 2001), which may have been because of the fact that some of the children with ADHD also had SMD, confounding group membership. In the recent study, children with SOR had more sensory problems (Short Sensory Profile); more somatic complaints (Child Behavioral Checklist; CBCL; Achenbach, 1991); were more likely to be withdrawn, anxious, or depressed (CBCL); and had more difficulty adapting (Leiter-R; Roid & Miller, 1997), but they had fewer attentional difficulties than children with a global clinical impression of only ADHD (Miller et al., 2012). These findings parallel those of Reynolds, Lane, and Gennings (2009), showing clinically significant anxiety in children with ADHD plus SOR, discussed in more detail in the next section. Altogether, these results suggest that there are likely at least two distinct subgroups within ADHD: those with sensory symptoms of SOR and those without. Further, individuals with a single diagnosis of either SMD or ADHD form two separate groups defined by differences on some parent report measures as well as their physiological responses to sensory stimuli.

Several studies combining physiological and behavioral responses to sensory stimulation in children with ASD have been conducted by Miller and colleagues (Miller, Reisman, McIntosh, & Simon, 2001; Schoen, Miller, Brett-Green, Reynolds, & Lane, 2008; Schoen et al., 2009). These studies contribute to a body of knowledge differentiating ASD from sensory integrative disorders. An initial pilot study suggested that children with ASD were physiologically under-responsive to sensation, with a depressed magnitude of EDA compared with typically developing children and children with a sensory integrative disorder. However, behavioral ratings from parents demonstrated significant SOR (Miller et al., 2001). Additionally, this sample demonstrated significant emotional over-responsivity and moderately impaired attention. In a later physiological study of children with ASD, two patterns of EDA were found: One group demonstrated higher levels of tonic EDA (e.g., general arousal state) and high reactivity across the sensory challenges (e.g., phasic reactions), and the other group demonstrated lowered tonic arousal and lower EDA (Schoen et al., 2008).

A follow-up study further compared both physiological and behavioral measures of sensory processing in children with ASD with a sample of children with SMD. Overall, the findings suggest that children with SMD have higher physiological reactivity to sensory challenges than children with ASD or typical controls, and children with ASD have a higher rate of non-responding to the initial presentation of a sensory stimulus (Schoen et al., 2009). In addition, although both clinical groups were rated high for behavioral symptoms of SMD, the ASD group had a greater degree of SUR and taste or smell sensitivity than the SMD sample. Similar findings are reported by Lane and colleagues using the Short Sensory Profile (Baker et al., 2008; Lane et al., 2011). This group of investigators also identified a behavioral cluster of sensory symptoms in children with ASD who had SUR and significant taste or smell sensitivity (Baker et al., 2008).

SMD and Cortisol

In other studies, investigators have utilized the SCP to examine the relationship between the ANS and the **neuroendocrine** system in children with ADHD who have comorbid SOR. This line of research has sought to elucidate the potential links between SOR and stress responses, ANS responses, and anxiety in children with ADHD.

Reynolds, Lane, and Gennings (2009) examined the impact of SOR on the activity of the HPA axis at baseline and in response to sensory challenges. Children in the ADHD group were divided into SOR (ADHD with sensory over-responsivity; ADHDs) and non-SOR (ADHD with typical sensory functioning; ADHDt) groups, and salivary **cortisol** was the measure of HPA activity. Differences in salivary cortisol between the ADHDt and ADHDs groups were found in response to a sensory challenge, and between the ADHDt and the typical group, with cortisol levels being significantly lower in the ADHDt group in both comparisons. These preliminary results support the premise that the presence of SOR may be considered a moderating variable used to create subgroups in diagnostic populations, particularly in ADHD research.

Lane and Reynolds also investigated whether neuroendocrine (using salivary cortisol) and electrodermal markers differed between groups, and could predict group membership, among children from 6 to 12 years of age with ADHD and SOR (ADHDs), ADHD and no SOR (ADHDt), and typical (Lane et al., 2010). Results indicated clear ADHDs and ADHDt groupings; children in the ADHDs group showed lower immediate post-SCP cortisol, higher cortisol at 25 to 30 minutes, and higher EDR orienting and domain response magnitudes.

SOR and Anxiety

SOR has been associated with anxiety in some populations of children. As noted previously, Lane, Reynolds, and Thacker (2010) found that children with ADHD and comorbid SOR were significantly more anxious than both children with ADHD without SOR and the typically developing controls. Higher anxiety scores and greater incidence of clinically significant anxiety were seen in children in the ADHDs group. Thus, children with ADHD and SOR formed a unique subgroup characterized by heightened magnitude of responses and stress reactivity when presented with a sensory challenge and higher levels of general anxiety. Professionals treating children with ADHD and SOR should be aware that these children may also have anxiety, and those professionals should discuss with families some options for prevention or treatment (Reynolds, Lane, & Gennings, 2009). This is consistent with other literature showing a relationship between SOR and anxiety in toddlers with ASD (Green, Ben-Sasson, Soto, & Carter, 2012). In fact, SOR was found to be a stable trait that emerges earlier than anxiety and also predicts later anxiety in this population (Green et al., 2012).

HERE'S THE POINT

- SMD has a high comorbidity with conditions such as ASD and ADHD; and may also co-occur with other psychiatric disorders such as BPD and bipolar disorder.
- There is evidence for the existence of a subgroup of individuals with ADHD that have SOR and high levels of stress and anxiety.
- Data suggest that children with SMD have significantly greater physiological reactivity to sensory challenges compared with children with ASD or typically developing children.

Summary and Conclusions

A wealth of neuroscience research related to sensory integration and sensory processing has been conducted during the past two decades. In examining the basic science foundation for sensory integration, by looking into both animal studies and basic human studies, we extend our understanding of the neural mechanisms underlying sensory integration. We need multiple tools to develop this understanding, and multiple approaches. Here we have presented information on sensory processing and integration in individuals without specific diagnoses, with sensory integrative and comorbid diagnoses, and in animal models reflecting sensory integrative deficits. Research continues to emerge, allowing us to differentiate primary disorders of sensory modulation from disorders of sensory modulation that are comorbid with other mental health diagnoses. Further, there is more and more information on the basics of multisensory integration. These bodies of work provide us with a foundation that may guide research and health-care funders to support future research and intervention. Certainly, this work provides the clinician with a better understanding of the strengths and needs each child brings to the table; better understanding of the mechanisms of sensory integrative and processing disorders provides a platform for planning assessment and intervention. Generally, the work presented here is not contextualized to the "real lives" of the children with whom we work. Contextualizing these findings will be important in future studies.

Where Can I Find More?

Bear, M. F., Connors, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain* (4th ed.). Philadelphia, PA: Wolters Kluwer.

Want to learn more about the brain and ways to measure brain functioning? This text contains an introduction to neuroanatomy, physiology, and measurement with up-to-date research from multiple areas of neuroscience.

Marcus, G., & Freeman, J. (Eds.). (2014). *The future of the brain: Essays by the world's leading neuroscientists*. Princeton, NJ: Princeton University Press.

This book of essays describes the technological advances that leading neuroscientists anticipate will enable us to map and eventually build working simulations of the human brain. The future of the brain sheds light on the breathtaking implications of brain science for medicine, rehabilitation, and psychological sciences.

References

Achenbach, T. M. (1991). *Manual for the child behavior checklist/4-18 and 1991 profile*. Burlington, VT: University of Vermont, Department of Psychiatry.

Adamson, A., O'Hare, A., & Graham, C. (2006). Impairments in sensory modulation in children with autism spectrum disorders. *British Journal of Occupational Therapy, 69,* 357–364.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. Washington, DC: American Psychiatric Association.

Arnsten, A. F. (2013). The neurobiology of thought: The groundbreaking discoveries of Patricia Goldman-Rakic 1937–2003. *Cerebral Cortex, 23,* 2269–2281.

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American Journal of Occupational Therapy, 62,* 564–573.

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1979). *Sensory integration and the child*. Los Angeles, CA: Western Psychological Services.

Baker, A. E., Lane, A., Angley, M. T., & Young, R. L. (2008). The relationship between sensory processing patterns and behavioural responsiveness in autistic disorder: A pilot study. *Journal of Autism and Developmental Disorders, 38,* 867–875.

Baranek, G. T. (2002). Efficacy of sensory and motor interventions for children with autism. *Journal of Autism and Developmental Disorders, 32,* 397–422.

Baranek, G. T., & Berkson, G. (1994). Tactile defensiveness in children with developmental disabilities: Responsiveness and habituation. *Journal of Autism and Developmental Disorders, 24,* 457–471.

Baranek, G. T., Boyd, B. A., Poe, M. D., David, F. J., & Watson, L. R. (2007). Hyperresponsive sensory patterns in young children with autism, developmental delay, and typical development. *American Journal of Mental Retardation, 112,* 233–245.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 47*(6), 591–601. doi:10.1111/j.1469-7610.2005.01546.x

Bavelier, D., Brozinsky, C., Tomann, A., Mitchell, T., Neville, H., & Liu, G. (2001). Impact of early deafness and early exposure to sign language on the cerebral organization for motion processing. *Journal of Neuroscience, 21,* 8931–8942.

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Carter, A. S., Kadlec, M. B., & Dunn, W. (2007). Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. *American Journal of Occupational Therapy, 61,* 584–592.

Brett-Green, B. A., Miller, L. J., Gavin, W. J., & Davies, P. L. (2008). Multisensory integration in children: A preliminary ERP study. *Brain Research, 1242,* 283–290. doi:10.1016/j.brainres.2008.03.090

Brett-Green, B. A., Miller, L. J., Schoen, S. A., & Nielsen, D. M. (2010). An exploratory event-related potential study of multisensory integration in sensory over-responsive children. *Brain Research, 1321,* 67–77. doi:10.1016/j.brainres.2010.01.04

Brown, C., Cromwell, R. L., Filion, D., Dunn, W., & Tollefson, N. (2002). Sensory processing in schizophrenia: Missing and avoiding information. *Schizophrenia Research, 55*(1-2), 187–195.

Brown, C., & Dunn, W. (2002). *The Adult Sensory Profile*. San Antonio, TX: Psychological Corporation.

Brown, C., Tollefson, N., Dunn, W., Cromwell, R., & Filion, D. (2001). The Adult Sensory Profile: Measuring patterns of sensory processing. *American Journal of Occupational Therapy, 55,* 75–82.

Caldji, C., Tannenbaum, B., Sharma, S., Francis, D. D., Plotsky, P. M., & Meaney, M. J. (1998). Maternal care during infancy regulates the development of neural systems mediating the expression of behavioral fearfulness in adulthood in the rat. *Proceedings of the National Academy of Sciences, USA, 95,* 5335–5340.

Chang, Y.-S., Gratiot, M., Owen, J. P., Brandes-Aitken, A., Desai, S. S., Hill, S. S., . . . Mukherjee, P. (2016). White matter microstructure is associated with auditory and tactile processing in children with and without sensory processing disorder. *Frontiers in Neuroanatomy, 9,* article 169.

Chang, Y.-S., Owen, J. P., Desai, S. S., Hill, S. S., Arnett, A. B., Harris, J., . . . Mukherjee, P. (2014). Autism and sensory processing disorders: Shared white matter disruption in sensory pathways but divergent connectivity in social-emotional pathways. *PloS One, 9*(7), e103038. doi:10.1371/journal.pone.0103038

Cohen, I. L. (1995). Behavioral profiles of autistic and nonautistic fragile X males. *Developmental Brain Dysfunction, 8,* 252–269.

Cohen, I. L., Sudhalter, V., Pfadt, A., Jenkins, E. C., Brown, W. T., & Vietze, P. M. (1991). Why are autism and the fragile-X syndrome associated? Conceptual and methodological issues. *American Journal of Human Genetics, 48,* 195–202.

Converse, A. K., Moore, C. F., Moirano, J. M., Ahlers, E. O., Larson, J. A., Engle, J. W., . . . Schneider, M. L. (2013). Prenatal stress induces increased striatal dopamine transporter binding in adult nonhuman primates. *Biological Psychiatry, 74,* 502–510.

Davies, P. L., Chang, W.-P., & Gavin, W. J. (2009). Maturation of sensory gating performance in children with and without sensory processing disorders. *International Journal of Psychophysiology, 72*(2), 187–197. doi:10.1016/j.ijpsycho.2008.12.007

Davies, P. L., & Gavin, W. J. (2007). Validating the diagnosis of sensory processing disorders using EEG technology. *American Journal of Occupational Therapy, 61,* 176–189.

Diamond, M. C., Rosenzweig, M. R., Bennett, E. L., Lindner, B., & Lyon, L. (1972). Effects of environmental enrichment and impoverishment on rat cerebral cortex. *Journal of Neurobiology, 3,* 47–64. doi:10.1002/neu.480030105

Dunn, W. (1999). *The Sensory Profile: Users manual*. San Antonio, TX: The Psychological Corporation.

Ellis, B. J., & Boyce, W. T. (2011). Differential susceptibility to the environment: Toward an understanding of sensitivity to developmental experiences and context. *Development and Psychopathology, 23,* 1–5.

Ernst, M. O. (2008). Multisensory integration: A late bloomer. *Current Biology, 18*(12), R519–R521.

Foxe, J. J., Morocz, I. A., Murray, M. M., Higgins, B. A., Javitt, D. C., & Schroeder, C. E. (2000). Multisensory auditory-somatosensory interactions in early cortical processing revealed by high-density electrical mapping. *Cognitive Brain Research, 10,* 77–83.

Friston, K. (2011). Functional and effective connectivity: A review. *Brain Connectivity, 1*(1), 13–36. doi:10.1089/brain.2011.0008

Gavin, W. J., Dotseth, A., Roush, K. K., Smith, C. A., Spain, H. D., & Davies, P. L. (2011). Electroencephalography in children with and without sensory processing disorders during auditory perception. *American Journal of Occupational Therapy, 65*(4), 370–377. doi:10.5014/ajot.2011.002055

Ghanizadeh, A. (2011). Sensory processing problems in children with ADHD, a systematic review. *Psychiatry Investigation, 8,* 89–94.

Green, S. A., Ben-Sasson, A., Soto, T. W., & Carter, A. S. (2012). Anxiety and sensory over-responsivity in toddlers and autism spectrum disorders: Bidirectional effects across time. *Journal of Autism and Developmental Disorders, 42,* 1112–1119. doi:10.1007/s10803-011-1361-3

Hagerman, R. J. (1996). Physical and behavioral phenotype. In R. J. Hagerman & A. Cronister (Eds.), *Fragile X syndrome: Diagnosis, treatment, and research* (pp. 3–87). Baltimore, MD: The Johns Hopkins University Press.

Hagerman, R. J., & Cronister, A. (Eds.). (2002). *Fragile X syndrome: Diagnosis, treatment, and research*. Baltimore, MD: The Johns Hopkins University Press.

Hellstrom, I. C., Dhir, S. K., Diorio, J. C., & Meaney, M. J. (2012). Maternal licking regulates hippocampal glucocorticoid receptor transcription through a thyroid hormone-serotonin-NGFI-A signaling cascade. *Philosophical Transactions of the Royal Society, 367,* 2495–2510.

Hitoglou, M., Ververi, A., Antoniadis, A., & Zafeiriou, D. I. (2010). Childhood autism and auditory system abnormalities. *Pediatric Neurology, 42*(5), 309–314. doi:10.1016/j.pediatrneurol.2009.10.009

Kempermann, G., & Gage, F. H. (1999). Experience-dependent regulation of adult hippocampal neurogenesis: Effects of long-term stimulation and stimulus withdrawal. *Hippocampus, 9,* 321–332. doi:10.1002/(SICI)1098-1063(1999)9

Kern, J. K., Trivedi, M. H., Garver, C. B., Grannemann, B. D., Andres, A. A., . . . Schroeder, J. L. (2006). The pattern of sensory processing abnormalities in autism. *Autism, 10,* 480–494.

Kientz, M. A., & Dunn, W. (1997). A comparison of the performance of children with and without autism on the sensory profile. *American Journal of Occupational Therapy, 51,* 530–537.

Kimball, J. G., Lynch, K. M., Stewart, K. C., Williams, N. E., Thomas, M. A., & Atwood, K. D. (2007). Using salivary cortisol to measure the effects of a Wilbarger protocol-based procedure on sympathetic arousal: A pilot study. *American Journal of Occupational Therapy, 61,* 406–413.

Kisley, M. A., Noecker, T. L., & Guinther, P. M. (2004). Comparison of sensory gating to mismatch negativity and self-reported perceptual phenomena in healthy adults. *Psychophysiology, 41,* 604–612.

Lacourse, M. G., Turner, J. A., Randolph-Orr, E., Schandler, S. L., & Cohen, M. J. (2004). Cerebral and cerebellar sensorimotor plasticity following motor imagery-based mental practice of a sequential movement. *Journal of Rehabilitation Research and Development, 41,* 505–524. doi:10.1682/JRRD.2004.04.0505

Lane, A. E., Dennis, S. J., & Geraghty, M. E. (2011). Brief report: Further evidence of sensory subtypes in autism. *Journal of Autism and Developmental Disorders, 41*(6), 826–831. doi.org/10.1007/s10803-010-1103-y

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience, 4*(8), 1–14. doi:10.3389/fnint.2010.00008

Lane, S. J., & Schaaf, R. C. (2010). Examining the neuroscience evidence for sensory driven neuroplasticity: Implications for sensory-based occupational therapy for children and adolescents. *American Journal of Occupational Therapy, 64,* 375–393. doi:10.5014/ajot.2010.09069

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders, 37,* 894–910.

Lesch, K. P., Meyer, J., Glatz, K., Flugge, G., Hinney, A., Hebebrand, J., ... Heils, A. (1997). The 5-HT transporter gene-linked polymorphic region (5-HTTLPR) in evolutionary perspective: Alternative biallelic variation in rhesus monkeys. Rapid communication. *Journal of Neural Transmission, 104,* 1259–1266.

Lewkowicz, D. J., & Röder, B. (2012). Development of multisensory processing and the role of early experience. In B. E. Stein (Ed.), *The new handbook of multisensory processing* (pp. 607–626). Cambridge, MA: MIT Press.

Liss, M., Saulnier, C., Fein, D., & Kinsbourne, M. (2006). Sensory and attention abnormalities in autistic spectrum disorders. *Autism, 10,* 155–172.

Liu, D., Diorio, J., Tannenbaum, B., Caldji, C., Francis, D. D., Freedman, A.,. . . Meaney, M.J. (1997). Maternal care, hippocampal glucocorticoid receptors and HPA responses to stress. *Science, 277,* 1659–1662.

MacPherson, P., McGaffigan, R., Wahlsten, D., & Nguyen, P. V. (2008). Impaired fear memory, altered object memory and modified hippocampal synaptic plasticity in split-brain mice. *Brain Research, 1210,* 179–188.

Mangeot, S. D., Miller, L. J., McIntosh, D. N., McGrath-Clarke, J., Simon, J., Hagerman, R. J., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology, 43,* 399–406.

McIntosh, D. N., Miller, L. J., Shyu, V., & Dunn, W. (1999). Overview of the Short Sensory Profile (SSP). In W. Dunn (Ed.), *The Sensory Profile: Examiner's manual* (pp. 59–73). San Antonio, TX: The Psychological Corporation.

Meaney, M. J. (2010). Epigenetics and the biological definition of gene x environment interactions. *Child Development, 81,* 41–79.

Menard, J., Champagne, D., & Meaney, M. J. (2004). Maternal care alters behavioral and neural activity patterns in the defensive burying paradigm. *Neuroscience, 129,* 297–308.

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *American Journal of Occupational Therapy, 6,* 135–140.

Miller, L. J., McIntosh, D. N., Shyu, V., & Hagerman, R. J. (1999). Sensory-modulation disruption, electrodermal responses, and functional behaviors. *Developmental Medicine and Child Neurology, 41,* 608–615.

Miller, L. J., Nielsen, D. M., & Schoen, S. A. (2012). Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology. *Research in Developmental Disabilities, 33,* 804–818. doi:10.1016/j.ridd.2011.12.005

Miller, L. J., Reisman, J. E., McIntosh, D. N., & Simon, J. (2001). An ecological model of sensory modulation: Performance of children with fragile x syndrome, autistic disorder, attention-deficit/hyperactivity disorder, and sensory modulation dysfunction. In S. S. Roley, E. I. Blanche, & R. C. Schaaf (Eds.), *Understanding the nature of sensory integration with diverse populations* (pp. 57–85). Tucson, AZ: Therapy Skill Builders.

Mollgarard, K., Diamond, M. C., Bennett, E. L., Rosenzweig, M. R., & Lindner, B. (1971). Quantitative synaptic changes with differential experience in rat brain. *Journal of Neuroscience, 2*(3), 113–128.

Moore, C. F., Gajewski, L. L., Laughlin, N. K., Luck, M. L., Larson, J. A., & Schneider, M. L. (2008). Developmental lead exposure induces tactile defensiveness in rhesus monkeys (Macaca mulatta). *Environmental Health Perspectives, 116,* 1322–1326.

Murray, M. M., Molholm, S., Michel, C. M., Heslenfeld, D. J., Ritter, W., Javitt, D. C., . . . Foxe, J. J. (2005). Grabbing your ear: Rapid auditory-somatosensory multisensory interactions in low-level sensory cortices are not constrained by spatial alignment. *Cerebral Cortex, 15,* 963–974.

Nithianantharajah, J., & Hannan, A. J. (2006). Enriched environments, experience dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience, 7,* 697–709.

Osterling, J. A., Dawson, G., & Munson, J. A. (2002). Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. *Development and Psychology, 14,* 239–251.

Owen, J. P., Marco, E. J., Desai, S., Fourie, E., Harris, J., Hill, S. S., . . . Mukherjee, P. (2013). Abnormal white matter microstructure in children with sensory processing disorders. *NeuroImage Clinical, 2,* 844–853. doi:10.1016/j.nicl.2013.06.009

Pantev, C., Ross, B., Fujioka, T., Trainer, L. J., Schulte, M., & Shulz, M. (2003). Music and learning induced cortical plasticity. *Annals of the New York Academy of Science, 999,* 438–450.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., & Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61,* 216–227.

Parham, L. D., Roley, S. S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a fidelity measure for research on the effectiveness of the Ayres Sensory Integration intervention. *American Journal of Occupational Therapy, 65,* 133–142.

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (2007). Somatosensory functions in boys with ADHD and tactile defensiveness. *Physiology and Behavior, 90,* 553–558.

Perry, W., Minassian, A., Feifel, D., & Braff, D. L. (2001). Sensorimotor gating deficits in bipolar disorder patients with acute psychotic mania. *Biological Psychiatry, 50,* 418–424.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118,* 2128–2148.

Rangasamy, S., D'Mello, S. R., & Narayanan, V. (2013). Epigenetics, autism spectrum, and neurodevelopmental disorders. *Neurotherapeutics, 10,* 742–756. doi:10.1007/s13311-013-0227-0

Restivo, L., Ferrari, F., Passino, E., Sgobio, C., Bock, J., Oostra, B. A., . . . Ammassari-Teule, M. (2005). Enriched environment promotes behavioral and morphological recovery in a mouse model for the fragile X syndrome. *Proceedings of the National Academy of Sciences of the United States of America, 102,* 11557–11562.

Reynolds, S., Devine, D. P., & Millette, A. (2012). Sensory and motor characterization in the post-natal valproate rat model of autism. *Developmental Neuroscience, 34,* 258–267.

Reynolds, S., Lane, S. J., & Gennings, C. (online 2009). The moderating role of sensory over-responsivity in HPA activity: A pilot study with children diagnosed with ADHD. *Journal of Attention Disorders, 13,* 468–478.

Reynolds, S., Lane, S. J., & Richards, L. (2010). Using animal models of enriched environments to inform research on sensory integration intervention for the rehabilitation of neurodevelopmental disorders. *Journal of Neurodevelopmental Disorders, 2*(3), 120–132.

Reynolds, S., Urruela, M., & Devine, D. P. (2013). Effects of environmental enrichment on repetitive behaviors in the BTBR T+tf/J Mouse Model of Autism. *Autism Research, 6,* 337–43. doi:10.1002/aur.1298

Rich, B. A., Vinton, D., Grillon, C., Bhangoo, R. K., & Leibenluft, E. (2005). An investigation of prepulse inhibition in pediatric bipolar disorder. *Bipolar Disorder, 7,* 198–203.

Rogers, S. J., Hepburn, S., & Wehner, E. (2003). Parent reports of sensory symptoms in toddlers with autism and those with other developmental disorders. *Journal of Autism and Developmental Disorders, 33,* 631–642.

Rogers, S. J., & Ozonoff, S. (2005). Annotation: What do we know about sensory dysfunction in autism? A critical review of the empirical evidence. *Journal of Child Psychology and Psychiatry, 46,* 1255–1268.

Roid, G. H., & Miller, L. J. (1997). *Leiter International Performance Scale*. Torrance, CA: Western Psychological Services.

Rosenthal, M. Z., Ahn, R., & Geiger, P. J. (2011). Reactivity to sensations in borderline personality disorder: A preliminary study. *Journal of Personality Disorders, 25,* 715–721.

Rosenzweig, M. R., & Bennett, E. L. (1972). Cerebral changes in rats exposed individually to an enriched environment. *Journal of Comparative and Physiological Psychology, 80,* 304–313. doi:10.1037/h0032978

Rosenzweig, M. R., Bennett, E. L., Diamond, M. C., Wu, S.-Y., Slagle, R. W., & Saffran, E. (1969). Influences of environmental complexity and visual stimulation on development of occipital cortex in rat. *Brain Research, 14,* 427–445. doi:10.1016/0006-8993(69)90120-6

Schaaf, R. C., Benevides, T., Blanche, E. I., Brett-Green, B. A., Burke, J. P., Cohn, E. S., . . . Schoen, S. A. (2010). Parasympathetic functions in children with sensory processing disorder. *Frontiers in Integrative Neuroscience, 4*(March), 4. doi:10.3389/fnint.2010.00004

Schaaf, R. C., Miller, L. J., Sewell, D., & O'Keefe, S. (2003). Children with disturbances in sensory processing: A pilot study examining the role of the parasympathetic nervous system. *American Journal of Occupational Therapy, 57,* 442–449.

Schneider, M. L., Moore, C. F., & Adkins, M. M. (2011). The effects of prenatal alcohol exposure on behavior: Rodent and primate studies. *Neuropsychological Review, 21,* 186–203.

Schneider, M. L., Moore, C. F., Adkins, M., Barr, C. S., Larson, J. A., Resch, L. M., & Roberts, A. (2017). Sensory processing in rhesus monkeys: Developmental continuity, prenatal treatment, and genetic influences. *Child Development, 88*(1), 183–197.

Schneider, M. L., Moore, C. F., Gajewski, L. L., Larson, J. A., Roberts, A. D., Converse, A. K., & DeJesus, O. T. (2008). Sensory processing disorder in a primate model: Evidence from a longitudinal study of prenatal alcohol and prenatal stress effects. *Child Development, 79,* 100–113.

Schneider, M. L., Moore, C. F., Gajewski, L. L., Laughlin, N. K., Larson, J. A., Gay, C. L., . . . DeJesus, O. T. (2007). Sensory processing disorders in a nonhuman primate model: Evidence for occupational therapy practice. *American Journal of Occupational Therapy, 61,* 247–253.

Schneider, M. L., Moore, C. F., Larson, J. A., Barr, C. S., DeJesus, O. T., & Roberts, A. D. (2009). Timing of moderate level prenatal alcohol exposure influences gene expression of sensory processing behavior in rhesus monkeys. *Frontiers in Integrative Neuroscience, 3,* 1–9.

Schoen, S. A., Miller, L. J., Brett-Green, B. A., & Nielsen, D. M. (2009). Physiological and behavioral differences in sensory processing: A comparison of children with autism spectrum disorder and sensory modulation disorder. *Frontiers in Integrative Neuroscience, 3*(November), 1–11. doi:10.3389/neuro.07029.2009

Schoen, S. A., Miller, L. J., Brett-Green, B. A., Reynolds, S., & Lane, S. J. (2008). Arousal and reactivity in children with sensory processing disorder and autism spectrum disorder. *Psychophysiology, 45,* S102.

Smith, J. R. (2012). Comforting touch in the very preterm hospitalized infant: An integrative review. *Advances in Neonatal Care, 12,* 349–365.

Stein, B. E., Stanford, T. R., & Rowland, B. A. (2014). Development of multisensory integration from the perspective of the individual neuron. *Nature Reviews Neuroscience, 15,* 520–535.

Stoeckel, M. C., Pollok, B., Schnitzler, A., Witte, O. W., & Seitz, R. J. (2004). Use-dependent cortical plasticity in thalidomide-induced upper extremity dysplasia: Evidence from somaesthesia and neuroimaging. *Experimental Brain Research, 156,* 333–341. doi:10.1007/s00221-003-1794-9

Talay-Ongan, A., & Wood, K. (2000). Unusual sensory sensitivities in autism: A possible crossroads. *International Journal of Disability, Development and Education, 47,* 201–212.

Tamm, L., Barnea-Goraly, N., & Reiss, A. L. (2012). Diffusion tensor imaging reveals white matter abnormalities in attention-deficit/hyperactivity disorder. *Psychiatry Research, 202,* 150–154.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the Short Sensory Profile. *American Journal of Occupational Therapy, 61,* 190–200.

Touge, T., Gonzalez, D., Wu, J., Deguchi, K., Tsukaguchi, M., Shimamura, M., . . . Kuriyama, S. (2008). The interaction between somatosensory and auditory cognitive processing assessed with event-related potentials. *Journal of Clinical Neurophysiology, 25,* 90–97.

Travers, B. G., Adluru, N., Ennis, C., Tromp, do P. M., Destiche, D., Bigler, E. D., . . . Alexander, A. L. (2012). Diffusion tensor imaging in autism

spectrum disorder: A review. *Autism Research, 5,* 289–313.
Weaver, I. C. G., Cervoni, N., D'Alessio, A. C., Champagne, F. A., Seckl, J. R., Szyf, M., . . . Meaney, M. J. (2004). Epigenetic programming through maternal behavior. *Nature Neuroscience, 7,* 847–854.
Werner, E., Dawson, G., Osterling, J. A., & Dinno, N. (2000). Brief report: Recognition of autism spectrum disorder before one year of age: A retrospective study based on home videotapes. *Journal of Autism and Developmental Disorders, 30,* 157–162.
West, R. W., & Greenough, W. T. (1972). Effect of environmental complexity on cortical synapses of rats: Preliminary results. *Behavioral Biology, 7,* 279–284. doi:10.1016/S0091-6773(72)80207-4
Yang, M., Perry, K., Weber, M. D., Katz, A. M., & Crawley, J. N. (2011). Social peers rescue autism-relevant sociability deficits in adolescent mice. *Autism Research, 4,* 17–27.
Zhang, L. I., Bao, S., & Merzenich, M. M. (2001). Persistent and specific influences of early acoustic environments on primary auditory cortex. *Nature Neuroscience, 4,* 1123–1130. doi:10.1038/nn745

CHAPTER 17

Using Sensory Integration Theory in Coaching

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To coach means to convey a valued colleague from where he or she is to where he or she wants to be.

—Evered & Selman, 1989, p. 32

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe six practices for implementing coaching: (1) joint planning, (2) action, (3) observations, (4) reflection, (5) provision and use of feedback, and (6) reframing.
- ✔ Define coaching, and describe the processes and characteristics involved in delivering effective coaching.
- ✔ Summarize the research evidence pertaining to strategies germane to coaching for caregivers of preschool-aged children with autism spectrum disorders (ASD).

Purpose and Scope

Ayres (1972) theorized that children with sensory integrative dysfunction benefitted from activities that provided the "just right" challenge and that were rich in tactile, vestibular, and proprioceptive sensation. She believed that these activities, when implemented by a skilled therapist working directly with a child, resulted in improvements in processing by the central nervous system, which, in turn, enabled children to act more effectively and efficiently in the context of everyday activities. This book is based on Ayres' theory.

In creating a Fidelity Measure for evaluating the effectiveness of sensory integrative therapy, Parham and colleagues (2007, 2011) defined Ayres Sensory Integration® (ASI) as a direct intervention approach: a therapist working *directly* with a child in particular ways to achieve particular outcomes. Even before Parham and colleagues (2007, 2011) defined ASI as a direct intervention approach, several theorists and researchers expressed the value of interventions focused on caregivers: enhancing sensation in the context of everyday activities, altering the environment, and applying additional theories to enable children to succeed *despite* sensory integrative dysfunction. Ayres' contemporaries remember her skill for helping parents understand their children in new ways (see Chapter 3, Composing a Theory: An Historical Perspective).

In creating the sensory diet, Patricia and Julia Wilbarger (1991; see also Chapter 18, Complementary Programs for Intervention) were perhaps the earliest of the theorist-practitioners to codify a nondirect intervention based in sensory integration (SI) theory. Not long afterward, Williams and Shellenberger (1996; see also Chapter 18, Complementary Programs for Intervention) published the Alert Program® in which they helped children and adults understand how to insert activities into everyday routines to improve self-regulation. Other theorist-practitioners also have utilized SI theory as the basis for similar programs (e.g., Zones of Regulation: http://www.zonesofregulation.com/index.html).

In the 1990s and early 2000s, drawing on the work of occupational therapists, educators, and others (e.g., DeBoer, 1995; Jaffe & Epstein, 1992; Schein, 1999), several theorist-researchers (e.g., Bundy, 2002; Dunn, 1990, 1992; Hanft & Pilkington, 2000; Hanft & Place, 1996) embraced *collaborative* or *process consultation* (Schein, 1999) as a particularly suitable intervention in school and at home. In recent years, believing the term *consultation* to be poorly understood, several occupational therapists (Graham, Rodger, & Ziviani, 2009, 2010, 2013, 2014; Kientz & Dunn, 2012) and early childhood educators (e.g., Hanft, Rush, & Shelden, 2004; Rush & Shelden, 2011) began to use the term *coaching*. Although we use the terms *coach* and *coaching* in this chapter, we believe that some authors (e.g., Bundy, 1995, 2002; Dunn, 1990, 1992; Hanft & Place, 1996; Kientz & Dunn, 2012) used the term *consultation* in a very similar way. In particular, we refer readers to Schein (1999) for an in-depth and scholarly treatment of process consultation. Although coaching is most commonly associated with athletics, the term originally (in the 1500s) referred to vehicles. Hence, Evered's and Selman's (1989) quote at the beginning of this chapter: "To coach means to convey a valued colleague from where he or she is to where he or she wants to be" (p. 32). In this chapter, we embrace the concept of a coach as a form of transportation.

Toll (2005) indicated that a coach helps others recognize what they know and are capable of doing and assists them to increase the knowledge and the effectiveness of what they do. Borrowing from these authors and from Rush and Shelden (2011), we define **coaching** as a means for assisting parents and teachers to be (and to feel) more effective in their own roles and to develop and refine strategies to promote children's everyday participation. Although parents and teachers are the most common coaching partners, therapists also coach other colleagues and older children or adults in order to help them identify and ameliorate issues that interfere with optimal participation. For simplicity, in the rest of this chapter, we refer to parents or teachers as coaching partners. Nonetheless, the information should directly transfer to most others receiving coaching.

In this chapter, we introduce coaching as an essential intervention approach for use by occupational therapists working with caregivers of children with SI dysfunction. The chapter is divided into five sections: (1) common myths associated with coaching; (2) defining practices for implementing coaching; (3) building the partnership and need for resources; (4) examples of coaching; and (5) research evidence for sensory-based interventions (SBIs) commonly used in coaching. Finally, we offer an appendix that may be useful for those wishing to enhance their knowledge of potential strategies to use in coaching parents and teachers of children with sensory integrative dysfunction.

Myths Surrounding Coaching

Before addressing coaching in detail, we want to debunk some myths surrounding the approach. We adapted the presentation of these myths from Hanft and Place (1996). Although written more than two decades ago, these myths remain true today.

Myth #1: Coaching Involves Therapists Training Teachers or Parents to Implement Therapy (i.e., Do the Job of the Therapist)

Although coaches sometimes teach parents or teachers how to implement therapeutic procedures, such procedures are just a small part of a coaching intervention. When sole interaction between the therapist and parent or teacher involves the therapist teaching the caregiver to perform therapeutic procedures in a prescribed way, that intervention does not meet the criteria for coaching; it lacks the fundamental collaborative character of coaching. Rather, such therapy is known as monitoring or indirect service.[1] Two such examples are the Wilbarger protocol (see Chapter 18, Complementary Programs for Intervention; P. Wilbarger & Wilbarger, 1991) or a handwriting program (e.g., Write Start; Case-Smith, Holland, & Bishop, 2011; Case-Smith,

[1]Therapists generally implement indirect service alongside another therapeutic approach—direct intervention or coaching—but rarely by itself.

Holland, Lane, & White, 2012) that a child practices in a particular way and that requires regular oversight by a parent or teacher. There are, of course, many other procedures commonly taught in the context of indirect service.

Myth #2: Because a Parent or Teacher Implements the Intervention, Therapists Spend Less Time with Children and, Therefore, Can Dramatically Increase Their Caseloads

This idea seems particularly prevalent in schools where the demand for productivity is high. In reality, coaching can take quite a lot of time (Dunn, 1992; Hanft & Place, 1996). To be effective, a therapist-coach meets regularly with coaching partners, sometimes intensively for a relatively short time and sometimes sporadically during a longer period. Although coaching may not mean less time from a therapist for an individual child, in the long run, coaching can spread a therapist's services further in a different way. Because teachers and parents come to think in new ways about children's needs, they may be able to generalize those principles to new situations and different children. Thus, other children, with or without disabilities or special needs, may benefit from coaching directed at ameliorating difficulties encountered in teaching or parenting a particular child. Similarly, when teens or young adults are the coaching partners, they learn to identify and solve problems associated with their own sensory integrative dysfunction and to advocate for their own needs. Thus, coaching promotes empowerment and independence of the coaching partner.

Myth #3: Coaching Is a Substitute for Direct Intervention

Coaching can be extremely powerful. We believe it should be a primary approach to service delivery with families and in schools. In other words, all children who require therapy to ameliorate difficulties meeting the demands of everyday life should have the benefit of coaching for their families and teachers. A growing body of research in collaborative consultation and coaching (e.g., Simpson, 2015) supports this view. However, the goals of coaching can be very different from those of direct intervention, and even when they are similar, the strategies differ substantially. Thus, in addition to coaching, some children also will require direct intervention to improve SI or to develop particular skills. Table 17-1 compares strategies used by a clinic-based occupational therapist with those of a school-based occupational therapist working with Kyle, the child featured in Chapter 11 (Interpreting and Explaining Evaluation Data) and Chapter 20 (Planning and Implementing Intervention Using Sensory Integration Theory). The school-based occupational therapist serves primarily as a coach to Kyle's teacher, whereas the clinic-based occupational therapist provides direct intervention to Kyle and coaching to his family. Both therapists share the same goals but the objectives that operationalize the goals differ as to the strategies for meeting the objectives.

HERE'S THE POINT

Common *myths* surrounding coaching must be debunked. The following are accurate statements about coaching.

- Coaching does *not* involve teachers or parents doing the therapist's job.
- At certain stages, coaching requires as much time as direct intervention and is, therefore, *not* a way to increase caseloads.
- Coaching is *not* a substitute for direct intervention.

Defining Practices for Implementing Coaching

Coaching is implemented to help others meet the demands of their own roles more effectively. Thus, a parent or the teacher who is a coaching partner owns the goal and has the final say about which strategies are best for attaining it. The major role of the therapist-coach is to help the coaching partner understand the situation (including the effect of sensory integrative dysfunction); set goals; and create, implement, and evaluate the effectiveness of strategies for meeting the goals.

According to Rush and Shelden (2011), coaching comprises five processes (joint planning, action, observation, reflection, and feedback), implemented in no set order. When coaching a parent or teacher of a child with sensory

TABLE 17-1 Comparison of Strategies Used by a Clinic-Based Occupational Therapist vs. a School-Based Occupational Therapist

GOAL	OBJECTIVE	PRIVATE PRACTICE OCCUPATIONAL THERAPIST*	SCHOOL OCCUPATIONAL THERAPIST**
Develop belief that he will succeed at things he values (i.e., that he is a desirable friend and playmate)	At least once a week, willingly play with other children in the neighborhood who are about his age	Coach Kyle's mother on strategies to help Kyle enter a group; identify activities where he could invite a peer Work with Kyle to develop particular skills he needs to play with other children (e.g., sport or game)	Coach Kyle's teacher to help Kyle enter a group; develop ideas for activities that he could do with a partner
Improve (gross) motor skills	Independently propel a swing by pumping	*Improved bilateral integration and ability to plan and produce sequenced projected limb movements* Work with Kyle on his ability to propel clinic swings; point out similarities between clinic and playground swings	Coach Kyle's teacher to help Kyle with this skill on the playground
Improve (fine) motor skills (i.e., handwriting); improve behavior	Complete at least three of four written assignments within the allotted class time	*Improved postural ocular control, bilateral integration and sequencing, visuomotor skill, sensory modulation* Design home program specifically addressing handwriting speed	Coach Kyle's teacher regarding location of Kyle's workspace (i.e., find quiet areas); adapt assignments
Improve behavior	Not hit classmates who accidentally bump into him	*Improve ability to modulate incoming sensory information;* explain tactile defensiveness and sensory modulation disorders to Kyle and his parents in terms they can understand; talk to Kyle about strategies he might use when he is feeling overwhelmed; coach Kyle's parents to help Kyle develop effective strategies	Explain relationship between Kyle's behavior, tactile defensiveness, and sensory modulation in educational terms; coach Kyle's teacher regarding location of Kyle's workspace (i.e., find quiet areas); find alternatives to other circumstances when fighting is a problem (e.g., while standing in line)

Note: Italics in the therapist's strategies reflect the proximal objectives established for Kyle; other strategies reflect a focus on distal objectives.
*Primary role: direct intervention; secondary role: coach to family.
**Primary role: coach to teacher.

integrative dysfunction, a therapist has access to SI theory as a frame for each of those processes. That is, SI theory helps a therapist-coach and the coaching partner understand a child's behaviors, develop strategies, and predict something about the effectiveness of those strategies. However, the therapist-coach also has access to a range of other practice theories. Regardless of which practice theories a therapist-coach employs, the goals of coaching are to ameliorate a problem that interferes with parenting or teaching the child and with the child's participation at home or in school. Here we slightly adapt Rush and Shelden's descriptions of each of the five processes of coaching:

- ***Joint planning***, in which a therapist-coach and coaching partner clarify the problem, set a goal, and identify actions to address the goal. Learning a process for clarifying the nature of a problem can, in itself, be an important benefit to parents and teachers (Schein, 1999).
- ***Action:*** Real-life events in the context of which coaching partners implement new strategies for parenting or teaching a child.

- ***Observation***, in which a therapist-coach observes the actions of a coaching partner for the purpose of providing feedback, or a coaching partner observes a coach in order to develop new ideas, strategies, or skills.
- ***Reflection***: Analysis, in the moment and later, of the implementation and outcomes associated with new strategies to determine if, and in what ways, the strategies require modification.
- ***Feedback***, provided in a respectful and reflective way, to expand coaching partners' understanding of the situation and the strategies.

To these, we add a sixth process: ***reframing***. Although reframing is a kind of reflection, it generally occurs early in the coaching process. Reframing involves enabling others to understand a child's behavior in a different way or to view behaviors from a new perspective (Bulkeley, Bundy, Roberts, & Einfeld, 2016; Bundy, 1995; Niehues, Bundy, Mattingly, & Lawlor, 1991). We speak of *re*-framing, rather than "setting the frame" (Schön, 1983, 1987) because, almost invariably, teachers and parents already have set a frame for a child's behavior. Setting the frame is only necessary when coaching recipients have no prior view or interpretation of a child's behavior. In the case of children with sensory integrative dysfunction, often the frame that teachers or parents have set is negative (Case-Smith, 1997). The child is framed as poorly disciplined, immature, destructive, careless, rigid, or over-reactive. The frame that teachers and parents have for viewing behavior determines how they will react to that child's behavior (i.e., the strategies they will use in teaching or parenting). By using SI theory to change the frame, we provide coaching partners with the basis for developing different strategies for interacting with students. In turn, these strategies often result in a dramatic lessening of problem behaviors because situations or activities that are difficult for the child can be avoided or made easier.

Reflective discussion is the essence of all coaching processes. Rush and Shelden (2011) described traits that ensure that coaching promotes discussion that is genuinely reflective. Not surprisingly, the first of those traits is: *consistency with the principles of adult learning*. Rush and Shelden (2011, p. 8) cited Cox (2006, p. 195):

> The person who will receive coaching support is perceived to be a mature, motivated and equal participant in a learning relationship with a facilitator (coach) whose role is to aid the learner in the achievement of his or her primarily self-determined learning objectives.

Coaching should be:

- Aimed at building coaching partners' capacity, performance, and reflective ability.
- As directive and hands-on as necessary. Although coaching is not about telling people what to do, a therapist-coach possesses knowledge and ideas for strategies that can be extremely helpful to parents and teachers. A therapist-coach may assist coaching partners to identify options or resources, share information to build knowledge, model an action, and provide feedback after the partner has engaged in self-reflection (Berg & Karlsen, 2007, cited in Rush & Shelden, 2011). The key to effective coaching is knowing *when, how,* and *why* to ask questions and share information or feedback (Rush & Shelden, 2011).
- Goal-oriented and solution-focused. Although the desired outcomes of coaching are clearly stated in the planning phases, the therapist-coach and coaching partner often refine the goals as the process unfolds. When the goals and underlying reasons for a child's performance difficulties become clearer, the coaching team also may alter strategies they developed for meeting the goals. As much as possible, coaching partners should develop the strategies. The therapist-coach primarily helps the partner figure out what will work (DeBoer, 1995; Schein, 1999). However, through time, each therapist-coach acquires a repertoire of strategies, which he or she can share judiciously. Appendix 17-A presents a list of strategies that may be useful in school settings. Some involve activities children commonly perform during the school day and that provide enhanced sensation. Some strategies are for problems commonly encountered by children with sensory integrative dysfunction but that do not necessarily incorporate enhanced sensation. Of course, many of the strategies could be adapted for home.

- Reflective. Through reframing, a therapist-coach aims to use SI (and other) theory to help a coaching partner attain new or deeper understanding of how various everyday tasks and environments affect a child. In so doing, goals become more precise and new strategies are identified. Throughout the process, both therapist-coach and coaching partner reflect on goals, strategies, and outcomes. What is working? What is not? Should strategies be tweaked, and, if so, in what ways? Are there things that the coaching partner needs in order to implement strategies more easily or more effectively?
- Collaborative. Coaching is a partnership. Both the therapist-coach and coaching partner possess knowledge and skills about a child and a situation (Hanft et al., 2004). A therapist-coach must learn what the partners believe about the child and situation and what they have tried previously. Parents and teachers have an opportunity to access specialized knowledge from a therapist-coach and, perhaps even more importantly, learn a process for reflecting on everyday problems as well as strategies for ameliorating the problems.

  Of course, both the therapist-coach and coaching partner have assumptions about the situation; it is important that each make the assumptions explicit to themselves and to each other (Schein, 1999). Further, there are many reasons why a strategy may not feel comfortable. Perhaps it does not reflect the coaching partner's style or values. Perhaps the partner just needs to practice until a strategy becomes his or her "own." Some partners need modeling before implementing a strategy. Some strategies just are not practical. When a strategy feels wrong, the coaching team tries to uncover the source of the discomfort so that they can make appropriate changes. The solution to the problem when a partner needs a model is very different from the solution when the partner simply needs practice. A therapist-coach must take care not to give up on a strategy because it does not work the first time. However, we also need to modify strategies that clearly are not working.
- Context driven. Coaching deals with goals germane to the everyday experiences and situations of parents, teachers, and the children that they parent or teach. Because contributors to a child's behavior depend on the context, strategies developed in coaching need to be context-specific (Joosten, Bundy, & Einfeld, 2012).

HERE'S THE POINT

- Coaching is a collaborative, reflective, hands-on process that involves the use of thoughtful feedback. It is context driven, and involves joint planning, observations, and actions by both the therapist-coach and coaching partner.
- A major purpose of coaching is to enhance the coaching partner's capacity for solving everyday, real life problems.
- The quality of the partnership between coach and coaching partner is key to success; the partnership must be built upon mutual respect for one another's expertise, previous experiences, and the priorities of the coaching partner.

Building the Partnership and Need for Resources

Building the Partnership

Not all aspects of coaching are visible; some aspects occur *behind the scenes*. In fact, coaching begins *before* the therapist-coach and coaching partner begin to work together. In preparing, both individuals, consciously or unconsciously, formulate expectations of what will happen during, and because of, coaching. Mattingly and Fleming (1994) suggested that expectations take the form of real or imagined stories created using information from several sources. These sources may include information that members of the coaching team have because they have worked together previously; information shared with one of them by a colleague or parent; past experiences that they have had working with or observing other therapists, teachers, or parents; or their own imaginations.

Formulating expectations is part of preparing. However, those expectations are "fiction." When we understand that, we are prepared to seek new information and build our expectations in response to the actual situation when we begin working together. In instances where a therapist-coach and coaching partner have worked together before, the stories or expectations that the two create may be very similar to what actually happens. However, in situations where the two have not worked together, one or both may have created stories, or set expectations, that impede the development of the relationship.

The relationship between therapist-coach and coaching partner is critical. Because it is not about solving a problem explicitly, thinking about forming the coaching relationship may feel "soft" and somehow less important. Thus, coaching teams (and, indeed, authors writing about coaching) may minimize the importance of formulating the relationship and move on to the "more important business" that lies ahead. However, when coaching teams fail to give enough consideration to forming an equal partnership, the process may go awry. For example, if the therapist-coach jumps in too quickly with solutions, the coach may give the impression of "knowing all the answers," which, in turn, may make the coaching partner feel dependent or even angry.

Clearly, perceived inequality in the relationship will hamper both the development of a partnership and the effectiveness of the process. This is particularly true when coaching teams have not worked together before or when one team member has considerably less experience than the other. Of course, a therapist-coach does sometimes offer solutions early in the process. A simple suggestion can go a long way toward gaining a coaching partner's interest in, and respect for, the process. However, we must guard against being perceived as the expert rather than a conduit. To be effective, a therapist-coach must demonstrate respect for the partner's knowledge and skills, willingness to respect the constraints under which the partner works, the ability to listen, and the ability to share knowledge and skills in a meaningful way.

Sometimes a parent or teacher may hesitate to enter into a coaching partnership. There are many valid reasons for that reluctance. The parent or teacher might believe a therapist is "invading" or interrupting the important business of home or classroom or judging the partner's abilities as a teacher or parent. An individual who has not previously worked with a therapist-coach might fear that coaching will be additional work or too much responsibility. That parent or teacher may perceive that therapy is a mysterious process carried out directly with a child and should not involve other adults. An effective and insightful coach understands that there are real reasons for reluctance to enter a coaching relationship. The power of coaching lays in the combined expertise of both team members. Thus, a therapist-coach does what it takes to facilitate the coaching partnership. Above all, the therapist-coach realizes that, although forming the relationship sometimes takes a great deal of time, the benefits are well worth the time and energy.

Therapists also sometimes hesitate to enter into coaching. Some believe that a coach must be an expert, and they do not feel as if they are experts. Others think "real therapy" involves "laying hands on" the child. Working with parents and teachers, although important, is secondary (Niehues et al., 1991). Still others, knowing that their mandate is to provide family- or client-centered care, become confused when parents or teachers seem to want only direct intervention.

We believe that many of these fears and beliefs arise from myths and misconceptions. We addressed some of those earlier in the chapter. Historically, occupational therapy practitioners were not trained as coaches. Although research has emerged in this area (Simpson, 2015), few therapists, particularly those implementing SI therapy, envision their primary role as a coach. Those therapists may have difficulty effectively explaining—or perhaps believing in—the power of coaching.

Attaining Needed Resources

All service provision requires resources. Coaching is no exception. Without proper resources, coaching cannot be effective. Thus, to some extent, a discussion of the required resources also describes some potential obstacles to coaching. Once again, the success of coaching depends on commitment and the strength of the partnership. Coaching requires a relationship of equals; each team member must respect the other's skills and knowledge and openly demonstrate that respect. Team members must communicate regularly, and the therapist-coach must listen actively to the coaching partner (DeBoer, 1995).

Success also requires shared skills. The coaching team must believe that, between them, they have the skills and commitment to solve the problem. Both must feel comfortable with their own professional identities; they must feel free to admit when they do not know an answer (Niehues et al., 1991). Each must be willing to take risks and credit the other for the contributions toward improving the child's performance (Case-Smith, 1997). In addition, the consultant must be willing to ask for and obtain other needed support.

Coaching requires time. It can be a challenge to schedule time to meet when a teacher or parent is not worried about what other children are doing or the therapist is not thinking about the next family or school (Hanft & Place, 1996). Providing coaching is a team decision, and the team has responsibility for providing resources. Consideration of the needed resources must be part of the decision-making process. For example, if, in school, it is not possible to schedule uninterrupted time before or after school or during breaks, the principal or some other adult may need to take responsibility for a class during coaching.

Asking a school principal for help is a strategy that some therapist-coaches use in schools. We describe this in a case illustration later in this chapter. In asking a school principal for assistance, that therapist-coach explained what she hoped to accomplish and why she needed a particular block of time. The principal agreed that he or another adult would be free during that half hour. The principal was willing to provide support once he understood the problem. Had the therapist not gone to talk with him, the principal probably would have remained unaware that there was a problem, and the teacher and therapist-coach might have given up needlessly. Further, the therapist, rather than the teacher, was responsible for securing the necessary assistance, although she must do so with the teacher's knowledge and approval.

PRACTICE WISDOM

Three decades ago, Bundy, Lawlor, Kielhofner, and Knecht (1989) reported the results of a large U.S. survey of special education administrators. When asked what one thing therapists could do to improve their effectiveness in public schools, these administrators commonly answered, "Be more assertive." This need continues today. In order to provide high-quality service, we need support from those around the child. Unless we make our needs known, those needs cannot be met.

Examples of Coaching

CASE STUDY ▪ REBECCA

Rebecca was a 5-year-old who was extremely hypersensitive to touch and minor pain but often had very delayed reactions to touch sensations. Sometimes 5 or more minutes passed after a minor incident, such as pinching her finger, before Rebecca erupted in tears and screams of agony: "This is gonna hurt me forever!" Initially, Rebecca's parents viewed Rebecca's reactions as melodrama. "After all, if she really were hurt, wouldn't she cry immediately?" they asked. Believing that Rebecca was only "acting" to get attention, her parents tried ignoring her wails and telling her that she was not hurt and was "acting silly." However, both responses only resulted in Rebecca screaming more loudly.

Using evaluation results in conjunction with parent observations, the therapist-coach explained Rebecca's behaviors in terms of SI theory. "Rebecca's sensory integrative dysfunction seems to result in taking longer to process sensation. When she does process it, Rebecca interprets many stimuli as painful." The result was that Rebecca's parents came to view this very problematic behavior in a different way. Rather than seeing her behavior as melodrama, they understood that Rebecca's intense but delayed reaction was the result of difficulty processing sensation. The frame was changed.

Reframing provided the basis for developing new strategies for parenting Rebecca. Working with the therapist-coach, Rebecca's parents used their new-found knowledge to develop new strategies for responding to her outbursts. They began to acknowledge that what Rebecca felt *was* pain and that she truly believed it would "hurt forever." They asked to see the hurt place and applied deep touch pressure and firm rubbing to the area. Using these strategies, they found that, although her reaction to minor pain remained intense and delayed, they could more easily console Rebecca.

Rebecca's parents felt better in their parenting role. They no longer dreaded taking Rebecca to friends' homes. They stopped believing that they had to apologize for Rebecca's "overreactions." They used their new strategies and behaved as though nothing out of the ordinary had occurred. Other adults picked up on this new strategy and also began to implement it. In this case, the feedback came from the adults in Rebecca's life. The new strategies worked, and everyone, including Rebecca, was more comfortable with Rebecca.

With the story of Rebecca, we illustrated an example of coaching with parents. However, coaching just as frequently happens at school. For example, a teacher who believed that a child constantly got into fistfights while standing in line because he was poorly disciplined behaved differently once she understood the child's tactile defensiveness and knew that the child was probably jostled accidentally from behind. With the old frame, the teacher made the child stand near the front of the line where she could keep an eye on him but, unfortunately, where others were more likely to jostle him accidentally. With the new frame in place, the teacher suggested that the child stand at the back of the line where there was less chance of unexpected touch, fewer fistfights, and less need for punishment for circumstances beyond the child's control.

CASE STUDY ▪ SHAW

Shaw, a seventh grader, had significant difficulty with organization. His case illustrates how coaching might happen with an older child or teen. His occupational therapist initially provided Shaw with direct services. She developed and implemented solutions to assist in managing Shaw's organizational difficulties. She installed dividers in his locker and arranged to have a second set of books at home. Such strategies were moderately successful. However, when the therapist became a coach rather than a direct service provider, she no longer assumed that she was the expert on Shaw's difficulties. Rather, *Shaw* became the expert. The therapist-coach helped him set his own goals. She was surprised when Shaw indicated that keeping track of his schedule was most important to him. Having identified the goal, Shaw developed a strategy for meeting it. He fastened a schedule permanently to his backpack. Because the schedule had been his idea, Shaw felt empowered to alter it to fit his needs and did so without assistance from his coach.

The concept of coaching is deceptively simple. The process, however, can be complicated. Success hinges on properly identifying the problem, which often is more difficult than it seems (Schein, 1999). Identifying the problem involves eliciting as much detail as we can about what the parent, teacher, or child is experiencing. We ask questions and make observations until we jointly pinpoint a solvable problem. We find out as much as we can about how and when a child's difficulties affect the child's participation and the parents' or teacher's abilities to carry out their own roles. We also try to learn which strategies have been tried by coaching partners and how well those strategies worked.

CASE STUDY ▪ DUNCAN

Duncan was an 8-year-old second grader in a combined first and second grade classroom. His teacher, having attempted unsuccessfully for more than a year to teach Duncan handwriting, asked for help from an occupational therapist. When asked about the problems that Duncan had reproducing letters with a pen or pencil, the teacher showed the therapist some of Duncan's papers. The letters were poorly formed and so light that they were barely legible. Upon questioning, the therapist learned that the teacher had attempted numerous strategies, and that she was currently using a "multisensory approach." The teacher indicated that Duncan practiced making letters with various media, including sand, rice, finger paint, chalk, and markers.

The therapist spent time in the classroom, and, as she watched, she noted that Duncan did not have a consistent pattern for forming letters; they looked different in each medium. The therapist realized that rather than practicing the same letter formation over and over, Duncan actually performed different motor patterns in each medium. When he formed the letter in finger paint, he used finger motions; however, when he wrote on the chalkboard, he used whole arm movements. Both of these were different from the motor patterns he used when he wrote with a pencil. Although most individuals would create letters that looked essentially the same no matter whether they used arm or finger movements, Duncan did not.

The therapist hypothesized that sensory-integrative-based dyspraxia affected Duncan's ability to learn cursive handwriting. She suggested to the educational team that she coach the teacher. Although the therapist believed that Duncan would probably benefit from direct therapy using a sensory integrative approach, she knew it could take months of direct intervention using SI to see a big effect on handwriting. In addition, although the therapist could have developed a direct intervention program that simply targeted handwriting, she could only have provided that intervention periodically. The teacher instructed Duncan daily in handwriting. Furthermore, the therapist knew far less than the teacher about teaching proper letter formation.

The teacher's openness to working with the therapist was an important factor in the recommendation for coaching. This master teacher had invested a lot of time and effort trying to teach Duncan to write. However, nothing worked. She knew that his problems required input from another professional and was eager for help. Although the teacher had taught letter formation for years, her knowledge of dyspraxia was limited. Therefore, she unknowingly developed a method to teach letter formation that "played to Duncan's weaknesses." This method resulted in Duncan's formulating several different motor responses for each letter. Because forming new motor responses was his greatest deficit, Duncan had not learned to write.

When the therapist presented her recommendation for coaching to Duncan's education team, including his parents and teachers, they agreed. In fact, her presentation of Duncan's motor planning difficulties and the potential benefits of coaching was so convincing that the physical education teacher also requested coaching. The therapist-coach listened carefully to the classroom teacher's problem teaching Duncan to write. She observed Duncan in his classroom. She did a little testing with Duncan (see Chapter 10, Assessing Sensory Integrative Dysfunction without the SIPT) and interpreted the results in light of what she saw and heard. She offered a new frame, explaining Duncan's difficulties as they applied to handwriting. She told the teacher that Duncan seemed to get poor feedback from touch and body movement. She did *not* explain the neuroanatomy of the tactile, vestibular, and proprioceptive systems. Rather, she made it clear that, in children such as Duncan, there is a *hypothesized* causal relationship between difficulty interpreting sensation from the body and the ability to learn new motor tasks. The therapist then went on to show the teacher that the multisensory teaching method she had devised unintentionally made learning handwriting more difficult. With the frame shifted in this way, the teacher understood Duncan's problems differently. The new frame also suggested new strategies.

Simple reframing was all that the teacher needed to understand the problem. She had known that Duncan was poorly coordinated and seemed not to know how his body moved. Therefore, she reasoned that providing a lot of sensation might help him learn to write better. However, she had not recognized that, with each new medium, Duncan formulated a new plan. She reasoned, "I guess I should pick one medium and stick with it." The therapist-coach agreed. Together, they concluded that Duncan needed to concentrate on writing with a pen or pencil. They discussed Duncan's difficulties forming letters and pressing hard enough. The therapist-coach, believing that Duncan was not getting adequate feedback from his body as he wrote, suggested a grease pencil because its increased resistance would provide a lot of feedback. The teacher agreed. The coaching team planned to meet the next week to discuss the outcomes.

The next week, the teacher reported that the grease pencil did not work. Duncan still did not press hard enough to make his handwriting legible and he did not enjoy using it. The teacher and therapist-coach devised a new plan for Duncan to write on carbonless paper, an office supply usually used to produce multiple copies simultaneously. The teacher taught Duncan to check periodically to see if he had been pressing down hard enough for his writing to come through.

Duncan responded very well to the carbonless paper. Within a short time, he learned to press harder and his writing became much more legible. After a couple of weeks, the teacher, working with the therapist-coach, decided that the carbonless paper might no longer be necessary. The teacher prepared Duncan for the change by trying to make him conscious of the amount of pressure he used when he wrote on the carbonless paper. She gave Duncan fewer carbonless papers each day.

Having explained that Duncan was not getting adequate feedback from his body, the therapist-coach suggested a different kind of writing implement. When Duncan's problem of not pressing hard enough on the paper persisted, the teacher and therapist-coach decided he should continue to use carbonless paper. Using standard paper, Duncan did not seem to be able to determine how hard was "hard enough." With the carbonless paper, "hard enough" became defined as hard enough to make marks appear on the paper underneath. This was the kind of feedback Duncan needed. The carbonless paper provided concrete evidence of whether he was writing hard enough. Consequently, the teacher did not have to give him verbal feedback. In a relatively short period of time, Duncan seemed to internalize the amount of pressure needed and no longer needed the prompt. This mutually developed strategy was agreeable to everyone. Ideally, all strategies are mutually developed and agreeable to all. However, *coaching partners* are primarily responsible for implementing the strategies, so the decision about whether a strategy is a good one rests with them (Schein, 1999).

As part of her role, the therapist-coach provided alterative writing utensils and paper. These materials were not really "adaptive equipment," per se. However, one important role of a therapist-coach is to provide adaptive or alternative devices and materials (Kielhofner, 2009). This is an important tool of coaching and a way of modifying the environment so that it better fits the needs of children with sensory integrative dysfunction.

Another important part of coaching was that the therapist-coach and teacher continued to meet regularly to identify and solve several difficulties that Duncan had in the classroom. As the teacher gained a greater understanding of Duncan's difficulties formulating new motor programs, she began to devise her own alternative teaching strategies. Initially, she liked to discuss her plans with the therapist-coach. However, the more she succeeded, the less input she needed. During one of their sessions, a couple of months into coaching, the teacher remarked, "You know, this all was once so new to me; now it seems so logical. I know that I will look at other students' problems differently from now on."

The therapist did similar coaching with the physical education (PE) teacher that was also highly successful. Duncan's PE class focused on fitness. The students spent the majority of their time doing basic skills: jumping jacks, push-ups, sit-ups, and running in place. Although the exercises were always the same, the teacher varied the order. If Duncan concentrated intensely, he could perform the exercises passably. But because this required inordinate effort, he often chose simply to stand and watch. When the therapist talked with the PE teacher, she learned that it was the "standing around" that bothered him.

In coaching the PE teacher, the therapist recommended some very simple adaptations to increase Duncan's participation. The therapist explained that Duncan would find the exercises easier if there were set routines that he could memorize. Furthermore, because Duncan's strongest channel for learning was auditory, she suggested it might be helpful if the PE teacher always called out the next exercise shortly before it changed and again at the time of the change. The PE teacher decided to stand relatively near Duncan to ensure that he could hear the instructions. He also decided to perform the exercises with the class, providing a visual model.

The therapist-coach used her knowledge of SI theory to help both teachers understand Duncan's difficulties with motor planning. In reframing, she helped them develop new strategies that worked. When the classroom teacher combined her knowledge of proper letter formation with the therapist's explanation of Duncan's motor planning deficits, the resulting strategies allowed Duncan to write legibly. Initially, Duncan did not participate in PE class. With a few simple modifications, however, Duncan became an active member of the class.

Pinpointing and refining the problem are particularly important. There might have been any number of reasons why Duncan's PE teacher sought the occupational therapist's assistance. However, what was really bothering Duncan's teacher was Duncan's failure to participate in class. The approach to solving the problem would have been entirely different if the PE teacher had been most bothered by Duncan's poor coordination. When refining the problem, we use caution not to assume that we already know what the problem is (Schein, 1999). We are mindful of the fact that the coaching partner is the expert on the problem.

PRACTICE WISDOM

Time spent to build strong coaching partnerships is well worth the effort. Mutual respect for one another's knowledge, skills, and previous experiences is essential in building those relationships.

HERE'S THE POINT

- Children with sensory integrative dysfunction confront many difficulties in everyday life. Their actions may be confusing to parents and teachers who, in turn, find it difficult to assume their own roles effectively.
- The combined difficulties of children and those seeking to interact effectively with them often lead to a child's referral to occupational therapy.
- Thus, SI theory is an important tool for working in schools and homes.
- Coaching enables parents and teachers to reframe children's behaviors and develop more effective strategies for teaching and parenting.
- Because children spend the majority of the day with parents and teachers, we argue that coaching should be a primary type of service delivery for children with sensory integrative dysfunction.

Research Evidence for Coaching- and Sensory-Based Interventions Used Commonly in Coaching with Families of Young Children with Autism

The benefits of coaching and collaborative consultation in occupational therapy have been fairly well established during the past two or more decades (e.g., Bulkeley et al., 2016; Davies & Gavin, 1994; Dreiling & Bundy, 2003; Dunn, 1990; Graham, Rodger, & Ziviani, 2009, 2010, 2013, 2014; Kientz & Dunn, 2012; Scott, 1997; Simpson, 2015). However, the body of evidence examining SBIs commonly employed in coaching fails to provide such clear direction (Case-Smith, Weaver, & Fristad, 2015; Watling & Hauer, 2015). Several problems contribute to the confusion surrounding these interventions. Chief among the problems is inconsistent terminology and methodological limitations in studies.

In the remainder of this chapter, we critique research about SBIs for preschool-aged children with autism spectrum disorders (ASDs). We decided to focus on research pertaining to children with ASDs because sensory challenges are a core feature of ASDs, and many occupational therapy interventions fall within a general category of SBIs. However, many of the strategies examined in this research are also used commonly in practice with older children and children who do not have an ASD.

In this section, we review and critique 16 studies employing SBIs that may be offered as strategies to coaching partners working with young children with autism (Table 17-2). We break those studies into five categories[2] (Table 17-3) described by Ashburner and colleagues (2014) according to the primary strategy employed. Within Table 17-2, we further consider two main groupings of SBIs: (1) prescriptive interventions and (2) responsive interventions. Prescriptive interventions have dominated the SBI research to date.

Generally prescriptive SBIs are characterized by passive application of sensation at a time and in a manner determined by the therapist or researcher. In contrast, responsive SBIs provide sensory experiences and opportunities in an individualized way to assist children to manage daily routines and challenges (Tomchek & Case-Smith, 2009). Figure 17-1 illustrates the relationships between ASI and two types of SBIs (prescriptive and responsive).

Although responsive strategies are more compatible with coaching interventions, and with

[2]In addition to the five categories listed in the table, Ashburner and colleagues (2014) described a sixth category: behavioral strategies to manage sensory challenges. We have not included this sixth category because, although therapists commonly use behavioral approaches with children with autism, the studies we located employed desensitization, a behavioral approach with underlying assumptions in direct conflict with the assumptions of SI theory.

ASI, some techniques described as prescriptive in Table 17-2 also can be used in responsive ways. Thus, we include research utilizing prescriptive interventions in this section. Following Table 17-3, we summarize and critique the studies in each of the five categories.

Mutual Information Sharing and Support (Category 1)

Mutual information sharing and support, along with the responsive strategies employed in the research described here, are integral parts of coaching (Rush & Shelden, 2011). In fact, the

TABLE 17-2 Summary of SBI Research Including Preschool Children with Autism

PRIMARY CATEGORY	FIRST AUTHORS	N	DESIGN	STRATEGY	LOCATION	RESPONSIVE/ PRESCRIPTIVE	FINDINGS
Mutual information sharing and support	Dunn, 2012	20	Group	Coaching	Home	Responsive	Significant improvements on goals, parent stress, parent feelings of competence
Mutual information sharing and support	Dunstan, 2008	1	Qualitative	Sensory diet/ Wilbarger	Home	Responsive	Positive impact on family routines; however, burden of implementation noted
Mutual information sharing and support	Bulkeley, 2016	3	Single case	Coaching/ sensory	Home	Responsive	Degree of change and maintenance of the intervention effect varied among participants
Embed sensory input to modulate arousal	Bonggat, 2010	3	Single case	Sensory diet	School	Prescriptive	No difference in time-on-task with a sensory diet compared with attention control
Embed sensory input to modulate arousal	Carter, 2005	1	Single case	Weighted vest	School	Prescriptive	No reduction in self-injury from a weighted vest
Embed sensory input to modulate arousal	Davis, 2011	1	Single case	Wilbarger/ brushing	Home	Prescriptive	Brushing had no significant effect on stereotypy
Embed sensory input to modulate arousal	Fertel-Daly, 2001	5	Single case	Weighted vest	School	Prescriptive	Decreased negative behavior; increased positive behaviors
Embed sensory input to modulate arousal	Hodgetts, 2011a	10	Single case	Weighted vest	School	Prescriptive	On-task behavior improved; in-seat behavior unchanged; mixed responses across participants
Embed sensory input to modulate arousal	Hodgetts, 2011b	6	Single case	Weighted vest	School	Prescriptive	Stereotypy not reduced by weighted vest

Continued

TABLE 17-2 Summary of SBI Research Including Preschool Children with Autism—cont'd

PRIMARY CATEGORY	FIRST AUTHORS	N	DESIGN	STRATEGY	LOCATION	RESPONSIVE/ PRESCRIPTIVE	FINDINGS
Embed sensory input to modulate arousal	Leew, 2010	4	Single case	Weighted vest	Home	Prescriptive	No decrease in negative behaviors or increase in joint attention; parent feelings of competence increased
Embed sensory input to modulate arousal	Murdock, 2014	30	Group	Platform swing	Clinic	Prescriptive	No significant difference on-task; engaged; stereotypy or out-of-seat behaviors immediately after swing
Embed sensory input to modulate arousal	Quigley, 2011	3	Single case	Weighted vest	Clinic	Prescriptive	No decrease in target behaviors with weighted vest
Embed sensory input to modulate arousal	Reichow, 2010	3	Single case	Weighted vest	School	Prescriptive	No difference between intervention and control conditions for weighted vest
Embed sensory input to modulate arousal	Schilling, 2004	4	Single case	Therapy ball seat	School	Prescriptive	Increased engagement and in-seat behavior with therapy ball seat
Embed sensory input to modulate arousal	Sniezyk, 2015	3	Single case	Sensory diet	School	Prescriptive	No causal relationship between intervention and behavior change
Self-regulatory strategies	Thompson, 2013	3	Single case	Social story of sensory strategies	School	Prescriptive	Desired behaviors increased; change in use of self-regulation strategies variable

TABLE 17-3 Categories for Ameliorating Sensory Challenges (Adapted from Ashburner et al., 2014)

MAJOR STRATEGY
1. Mutual information sharing and support
2. Adapting tasks or environment
3. Embedding sensory input into everyday activity to modulate arousal
4. Self-regulatory strategies
5. Universal design

Note: Categories 1 to 4 can be applied in a sequential manner; Category 5 is applied to benefit all children, potentially alongside individual interventions.

three studies in this category (Bulkeley et al., 2016; Dunn, Cox, Foster, Mische-Lawson, & Tanquary, 2012; Dunstan & Griffiths, 2008) might be considered in a general way as studies of coaching effectiveness. They provide promising evidence in support of coaching for managing the sensory challenges of children with autism and make important contributions to service delivery and future research (Tomlin & Swinth, 2015). We highlight the details of the studies in Here's the Evidence boxes.

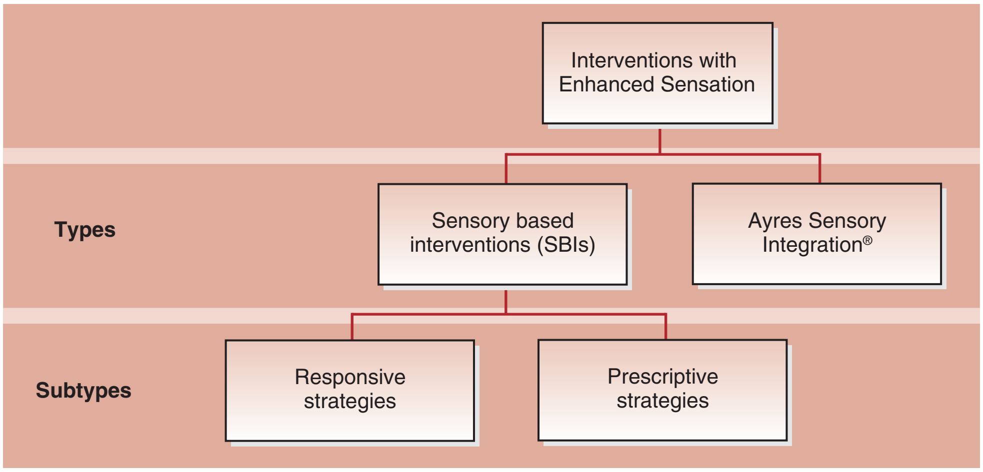

FIGURE 17-1 ASI, SBIs, and subtypes.

HERE'S THE EVIDENCE

Dunn and colleagues (2012) provided ten 1-hour coaching sessions to parents. Together, parents and researchers identified goals to promote participation in family routines and develop parental competence. They measured outcomes using the Canadian Occupational Performance Measure, goal attainment scaling, the Parenting Stress Index, and the Parenting Sense of Competence Scale. To ensure fidelity to the intervention, the therapist recorded the sessions, maintained coaching logs, and engaged in mentoring and team discussions. Goals, parent perceptions of competence, and perceived stress all improved because of the intervention. However, parents completed all outcome measures together with the therapist who provided the intervention, imposing some limitations on the independence of these ratings.

HERE'S THE EVIDENCE

Dunstan and Griffiths (2008) reported the results of a coaching intervention in an in-depth case study of a 4-year-old boy with autism. During a 5-week period, they provided education about sensory issues and support for the family and prescribed a sensory diet and the Wilbarger brushing protocol. Observation sessions and interviews with family members yielded positive views on the impact of the intervention. The mother highlighted the value of knowledge and reframing of behavior:

> The result of the assessment, it was just like light bulbs going off . . . and it was so obvious once they had pointed it out. . . . If you kind of understand why he's feeling the way he's feeling, or why he's doing what he's doing then it tends to be a lot easier. (Dunstan & Griffiths, 2008, p. 10)

Despite the benefits, family members noted a need for ongoing support to avoid being overwhelmed by too much information and too many demands.

HERE'S THE EVIDENCE

Bulkeley and colleagues (2016) explored the effectiveness of a sensory-based, family-centered coaching approach to changing problematic routines for young children with autism. Three mothers of young children with autism, atypical sensory processing, and global developmental delay each participated in a single-case experimental ABA-design study. Mothers selected a problematic daily routine linked to sensory challenges as the focus of four intervention sessions provided at home. Changes in the mothers' perceptions of the children's behavior were the primary outcome, measured daily on a visual analog scale. Bulkeley and colleagues analyzed the data visually and descriptively. The degree and maintenance of the intervention effect varied among participants.

Adapting Tasks or the Environment (Category 2)

Occupational therapy practice models and guidelines for children with autism are replete with the importance of adaptations to the task and environment (Rodger, Ashburner, Cartmill, & Bourke-Taylor, 2010; Tomchek & Case-Smith, 2009). Such adaptations are often the hallmark of coaching interventions. Many occupational therapists working with individuals with autism use adaptations to manage sensory challenges (Ashburner et al., 2014; Kadar, McDonald, & Lentin, 2012). However, as Baranek (2002) pointed out, their effectiveness is rarely examined empirically. Dunstan and Griffiths (2008) briefly mentioned environmental modifications in their case study, described previously. Dunn and colleagues (2012) provided examples of adaptation: a timer to assist with task completion, including music in morning routines, and arranging alternative activities when siblings were playing soccer. Bulkeley and colleagues (2016) offered ways of minimizing the noise associated with a hair dryer as well as adaptations of a mealtime routine.

Embedding Sensory Input into Everyday Activity to Modulate Arousal (Category 3)

Therapists commonly use sensory diets and approaches such as the Alert Program® (see Chapter 18, Complementary Programs for Intervention) in coaching interventions as a way of embedding sensory input into everyday activities. Very often coaches suggest embedding enhanced sensation into daily activity in order to help a child modulate arousal. Most of the 16 SBI studies reported here examined strategies for using enhanced sensory input to modulate arousal: weighted vests, alternative seating, sensory diets, the Wilbarger protocol, and platform swings. However, with the exception of Dunn and colleagues (2012), Dunstan and Griffiths (2008), and Bulkeley and colleagues (2016), who embedded sensory input into everyday activity as needed, all of the research in this category involved prescribed strategies done at set times and in a standard manner.

Given discrepancies between the ways that therapists use the prescriptive strategies described here in practice and the ways researchers employ them in studies, it is not surprising that there is little consensus on their effectiveness. Mixed findings reveal a need to target sensory interventions more effectively but do not support their hasty dismissal, as critics often conclude. We discuss existing research on each of these prescribed strategies next, recognizing that clearly there is a need for further research.

Weighted Vests

Weighted vests exert deep pressure, hypothesized to be calming and organizing, with the intent of facilitating increased attention, in-seat behavior, upright posture, and length of time on task. Olson and Moulton (2004b) used weighted vests to reduce stereotypy and self-injury. Most occupational therapists working with children with autism report prescribing weighted vests (Olson & Moulton, 2004a, 2004b). However, unlike in practice, where weighted vests are generally a part of a responsive intervention framework, in the research described here, weighted vests are a stand-alone prescribed intervention. Duration of wear and amount of weight vary markedly among studies. Only one study reported positive outcomes for all participants (Fertel-Daly, Bedell, & Hinojosa, 2001); two reported mixed findings (Hodgetts, Magill-Evans, & Misiaszek, 2011a; Leew, Stein, & Gibbard, 2010); the remaining four found no positive effects (Carter, 2005; Hodgetts, Magill-Evans, & Misiaszek, 2011b; Quigley, Peterson, Frieder, & Peterson,

HERE'S THE EVIDENCE

Researchers report a variety of durations for wearing weighted vests: 4 minutes (Quigley et al., 2011), 5 minutes (Carter, 2005), 10 minutes (Reichow et al., 2010), 20 minutes (Hodgetts et al., 2011a, 2011b), 30 minutes (Leew et al., 2010), and 2 hours (Fertel-Daly et al., 2001). Fertel-Daly and colleagues provided a rationale for length of wear time based on anecdotal reports and an early animal study proposing an initial surge in arousal before calming when deep pressure was applied for 2 hours. Researchers generally prescribe the vest once a day, but total duration of the intervention ranged from two sessions (Leew et al., 2010) to 2 years (Reichow et al., 2010). Amount of weight is another variable, ranging from 5% of the child's body weight (Hodgetts et al., 2011a, 2011b; Leew et al., 2010; Quigley et al., 2011; Reichow et al., 2010) to 7.5% (Carter, 2005) and up to 10% (Hodgetts et al., 2011a, 2011b; Quigley et al., 2011) or a standard weight of 1 pound (Fertel-Daly et al., 2001). Researchers reported anecdotal evidence or common practice as the primary rationale for determining weight.

2011; Reichow, Barton, Sewell, Good, & Wolery, 2010). See the Here's the Evidence box for more details on studies of the effectiveness of weighted vests.

Alternative Seating

Sitting on a therapy ball is thought to provide opportunities to move and enhance sensation in acceptable ways in a classroom. In turn, movement encourages a calm, alert state for focused work. Schilling and Schwartz (2004) reported increased engagement and in-seat behavior for four preschool boys who, for a span of 3 weeks, sat on therapy balls for 5 to 10 minutes during class activities. Classroom staff and some families endorsed the therapy balls. Although there has been only one study of the balls with preschoolers, and they were used in a prescribed way, the positive findings suggest that therapy balls as alternative seating are worthy of further investigation.

HERE'S THE EVIDENCE

Sniezyk and Zane (2015) individually prescribed sensory activities to three children to reduce stereotypy that interfered with classroom participation. The researchers described an ABA single case design; however, one participant completed only very brief baseline and intervention phases (AB design) because the child's stereotypy increased on introduction of the intervention. Although the other two participants' problem behaviors decreased during the intervention, the behaviors did not return to baseline levels when the intervention was withdrawn. Therefore, the researchers concluded that the intervention was not linked to behavior change; however, an alternative interpretation is that the intervention had positive long-term effects.

Sensory Diets

Sensory diets are a mechanism for harnessing the sensory features of activities to promote function in natural environments (J. Wilbarger & Wilbarger, 2002a; see also Chapter 18, Complementary Programs for Intervention). Wilbarger and Wilbarger described sensory diets as responsive and individually constructed and scheduled according to the context, the sensory needs of a child, and the demands of a chosen activity. Thus, sensory diets are often part of coaching interventions. Nonetheless, findings from two studies with preschool-aged children with ASD (Bonggat & Hall, 2010; Sniezyk & Zane, 2015) yielded mixed evidence on their effectiveness. However, the sensory diets were not necessarily used in responsive ways (see the Here's the Evidence box).

Wilbarger Approach

The Wilbarger approach (J. Wilbarger & Wilbarger, 2002b; see also Chapter 18, Complementary Programs for Intervention) is a professionally guided program for managing sensory defensiveness that includes: mutual information sharing and support, a sensory diet embedded in daily routines, and an optional guided program that involves applying deep pressure (brushing using a specific brush) and joint compression at regular intervals. See the Here's the Evidence box.

HERE'S THE EVIDENCE

Bonggat and Hall (2010) compared sensory diets (brushing and joint compression, rolling on a therapy ball, and swinging in a hammock) with an attention-control treatment. They prescribed different activities for each of the three children but administered the activities at the same time daily rather than following the recommended responsive procedure for sensory diets (Case-Smith et al., 2015; J. Wilbarger & Wilbarger, 2002a). The researchers reported increases in on-task behavior for all participants but no difference between intervention and control conditions. Although they concluded that sensory diets are ineffective, one might cautiously (given problems with study design) conclude that *both* sensory diet activities *and* one-on-one attention-control activities are viable options for improving attention to task.

HERE'S THE EVIDENCE

Davis, Durand, and Chan (2011) reported the results of a single case design study using brushing and joint compression to reduce stereotypy in a 4-year-old boy with autism. The child's mother or a behavior therapist administered the protocol seven times a day for 6 weeks. Although the Wilbarger protocol is not commonly applied to reduce stereotypy and the deep pressure and joint compression techniques are not recommended for use in isolation from other sensory strategies, these researchers hypothesized that the intervention would provide a similar level of sensory stimulation to that received from stereotypic movements. However, they found no change, providing no support for brushing and joint compression to reduce stereotypy. Because they employed brushing for a different outcome than that for which it is intended, their conclusion that the approach is ineffective must be considered with caution.

Platform Swing

Platform swings are a means of providing movement and vestibular input without making significant postural demands. The type of movement (i.e., slow vs. fast; angular vs. linear) determines whether the input is calming or alerting. We found only one study (Murdock, Dantzler, Walker, & Wood, 2014) of the effectiveness of platform swings with children with autism. In this study, the platform swing was used as a stand-alone intervention for a relatively short time immediately before a focused task. Murdock and colleagues (2014) investigated the prescribed use of a platform swing with 30 preschoolers with autism for increasing engagement and on-task behaviors and reducing stereotypy and time out-of-seat. Children randomly received 5 minutes on a platform swing (intervention) or 5 minutes watching a movie (control) as a break from table-top activities. The researchers found no significant differences between intervention and control groups. They, therefore, did not recommend the platform swing, although their conclusion applies only to a restricted context and not usual practice.

Self-Regulatory Strategies (Category 4)

Ashburner and colleagues (2014) reported that about half of occupational therapists use self-management strategies, including social stories, to help children with autism manage sensory challenges (Tomchek & Case-Smith, 2009). In Chapter 18 (Complementary Programs for Intervention), we include the Alert Program® (Williams & Shellenberger, 1996) that therapists use commonly in the context of coaching interventions to help with self-regulation. However, we found only one study of self-regulatory strategies with young children with autism. Thompson and Johnston (2013) identified individual goals for three preschoolers and read social stories to each child before a targeted activity. All three children increased the target behaviors and two increased their use of self-regulation strategies. The preschool staff noted increased participation in activities and a reduction in required support.

Universal Design (Category 5)

Principles of universal design to increase person-environment fit for individuals with ASDs have emerging support (Ashburner et al., 2014; Rodger, Ashburner, & Hinder, 2012; Tomchek & Case-Smith, 2009). They are recommended in online media about autism-friendly environments (e.g., https://www.theatlantic.com/

health/archive/2015/04/making-theater-autism-friendly/388348/), on websites about Universal Design for Learning (e.g., http://www.udlcenter.org/aboutudl), and in textbooks (Woronko & Killoran, 2011). Although we found no research of the effectiveness of universal design principles, such research clearly is warranted (Ashby, 2011; Rodger et al., 2010).

HERE'S THE POINT

- Studies embedding sensory input into daily activity to modulate arousal and change behavior yielded mixed findings and were often fraught with methodological limitations.
- Thus, although some of the strategies have promise, the evidence does not allow us to conclude definitively that they either are or are not effective.
- Studies of mutual information sharing and support (Bulkeley et al., 2016; Dunn et al., 2012; Dunstan & Griffiths, 2008) most closely reflect the characteristics inherent to coaching listed at the beginning of this chapter. They also yielded some of the most positive results.
- Collaboration between a therapist-coach and coaching partners (i.e., families and teachers) helps to ensure that interventions are individualized and responsive.

Summary and Conclusions

In coaching, we offer partners (e.g., parents, teachers) access to SI (and other) theory as a way of understanding behavior. Based on a new frame, the therapist-coach assists a coaching partner to understand the behavior differently and develop new strategies for addressing it. The expected short-term outcomes of coaching are a coaching partner who feels, and is, more effective in his or her own roles and a child who participates more fully because of an improved fit between the child's needs, the tasks he or she must do, and the supportiveness of the environment. In other words, coaching enables children with sensory integrative dysfunction to succeed *despite* their limitations. The long-term outcomes of coaching are that coaching partners learn a process for identifying and refining problems and for developing strategies to ameliorate those problems and can apply those in different situations.

Coaching is a powerful means of delivering occupational therapy to individuals with sensory integrative dysfunction. The overall goal of coaching is to help coaching partners (e.g., parents, teachers) be, and feel, more effective in their own roles. Coaching involves joint planning, observation, action, reflection, feedback, and reframing**.** The evidence for the success of coaching as an intervention to improve children's participation in everyday life and parents' and teachers' feelings of effectiveness in their own roles is growing. However, more research is needed.

Coaching is, by definition, a collaborative process. We note, however, that even when therapists collaborate with families, the interventions they develop together do not always turn out to be manageable from the families' perspective. When families simply agree to participate in a particular intervention or study, rather than collaborating on its development, the danger of imposition is even greater. The intensity of some interventions places significant demands on families, which may not be sustainable. Davis and colleagues (2011) studied the Wilbarger brushing protocol with the participant potentially receiving 294 occasions of intervention (if administered as proposed). Can such an intervention find a place in the busy schedules of families? The amount of intervention required to achieve particular outcomes is unclear and requires research.

The preponderance of evidence regarding the effectiveness of strategies commonly offered to coaching partners for managing the sensory challenges of young children with autism falls into two categories: embedding sensory input in everyday activity and mutual information sharing and support. Overall the research is limited, results are mixed, and, as previously noted, the research is fraught with methodological concerns. Further, a lack of Fidelity Measurement in most studies means uncertainty about the delivery of the intervention and raises questions about conclusions.

Finally, some authors of the studies that we reviewed here (Leew et al., 2010; Quigley et al., 2011; Sniezyk & Zane, 2015) referred to their interventions as "SI therapy." However, in no case did the intervention comply with criteria specified in Parham and colleagues' (2007) Fidelity Measure for ASI. As noted earlier, Parham and colleagues' Fidelity Measure applies to direct intervention, and, therefore, it does not reflect the characteristics of coaching interventions.

Where Can I Find More?

Friedman, M., & Woods, J. (2012). Caregiver coaching strategies for early intervention providers: Moving toward operational definitions. *Infants & Young Children, 25*(1), 62–82. doi:10.1111/j.1365-2753.2006.00674.x

Hanft, B. E., Rush, D. D., & Shelden, M. L. (2004). *Coaching families and colleagues in early childhood.* Baltimore, MD: Paul H. Brookes Publishing Company.

Kessler, D., & Graham, F. (2015). The use of coaching in occupational therapy: An integrative review. *Australian Occupational Therapy Journal, 62,* 160–176. doi:10.1111/1440-1630.12175

McConachie, H., & Diggle, T. (2007). Parent implemented early intervention for young children with autism spectrum disorder: A systematic review. *Journal of Evaluation in Clinical Practice, 13*(1), 120–129. doi:10.1111/j.1365-2753.2006.00674.x

Schein, E. H. (1999). *Process consultation revisited: Building a helping relationship.* Menlo Park, CA: Addison-Wesley.

References

Ashburner, J., Rodger, S., Ziviani, J., & Hinder, E. (2014). Optimizing participation of children with autism spectrum disorder experiencing sensory challenges: A clinical reasoning framework. *Canadian Journal of Occupational Therapy, 81*(1), 29–38. doi:10.1177/0008417413520440

Ashby, J. (2011). Commentary on "Helping children with autism spectrum disorders and their families: Are we losing our occupation-centered focus?" *Australian Occupational Therapy Journal, 58*(5), 390–391. doi:10.1111/j.1440-1630.2011.00961.x

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Baranek, G. T. (2002). Efficacy of sensory and motor interventions for children with autism. *Journal of Autism and Developmental Disorders, 32*(5), 397–422. doi:10.1023/A:1020541906063

Berg, M. E., & Karlsen, J. T. (2007). Mental models in project management coaching. *Engineering Management Journal, 19*(3), 3–13.

Bonggat, P. W., & Hall, L. J. (2010). Evaluation of the effects of sensory integration-based intervention by a preschool special education teacher. *Education & Training in Autism & Developmental Disabilities, 45*(2), 294–302. Retrieved from http://ezproxy.library.usyd.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=508169319&site=ehost-live

Bulkeley, K., Bundy, A., Roberts, J., & Einfeld, S. (2016). Family-centered management of sensory challenges of children with autism: A single-case experimental design. *American Journal of Occupational Therapy, 70,* 7005220040. doi:10.5014/ajot.2016.017822

Bundy, A. C. (1995). Assessment and intervention in school-based practice: Answering questions and minimizing discrepancies. *Physical and Occupational Therapy in Pediatrics, 15,* 69–88.

Bundy, A. C. (2002). Using sensory integration theory in schools: Sensory integration and consultation. In A. C. Bundy, S. J. Lane, & E. A. Murray (Eds.), *Sensory integration: Theory and practice* (2nd ed.), pp. 310–332. Philadelphia, PA: F. A. Davis.

Bundy, A. C., Lawlor, M. C., Kielhofner, G., & Knecht, H. (1989, April). Educational and therapeutic perceptions of school system practice. Paper presented at the Annual Conference of the American Occupational Therapy Association, Baltimore, MD.

Carter, S. (2005). An empirical analysis of the effects of a possible sinus infection and weighted vest on functional analysis outcomes of self-injury exhibited by a child with autism. *Journal of Early and Intensive Behavior Intervention, 2*(4), 252–258. Retrieved from http://researchautism.net/publications?filters[subtitle]=Journal%20of%20Early%20and%20Intensive%20Behavior%20Intervention

Case-Smith, J. (1997). Variables related to successful school-based practice. *Occupational Therapy Journal of Research, 17,* 133–153.

Case-Smith, J., Holland, T., & Bishop, B. (2011). Effectiveness of an integration handwriting program for first grade students: A pilot study. *American Journal of Occupational Therapy, 65,* 670–678.

Case-Smith, J., Holland, T., Lane, A., & White, S. (2012). Effect of a co-teaching handwriting program for first graders: One group pretest-posttest design. *American Journal of Occupational Therapy, 66,* 396–405.

Case-Smith, J., Weaver, L., & Fristad, M. A. (2015). A systematic review of sensory processing interventions for children with autism spectrum disorders. *Autism, 19,* 133–148. doi:10.1177/1362361313517762

Cox, E. (2006). An adult learning approach to coaching. In D. R. Stober & A. M. Grant (Eds.), *Evidence-based coaching handbook: Putting best* *practices to work for your clients* (pp. 193–217). Hoboken, NJ: Wiley & Sons.

Davies, P. L., & Gavin, W. J. (1994). Comparison of individual and group/consultation treatment methods for preschool children with developmental delays. *American Journal of Occupational Therapy, 48,* 155–161.

Davis, T. N., Durand, S., & Chan, J. M. (2011). The effects of a brushing procedure on stereotypical behavior. *Research in Autism Spectrum Disorders, 5*(3), 1053–1058. doi:10.1016/j.rasd.2010.11.011

DeBoer, A. L. (1995). *Working together: The art of consulting*. Longmont, CO: Sopris.

Dreiling, D. S., & Bundy, A. C. (2003). A comparison of consultative model and direct-indirect intervention with preschoolers. *American Journal of Occupational Therapy, 57,* 566–569.

Dunn, W. (1990). A comparison of service provision models in school-based occupational therapy services: A pilot study. *Occupational Therapy Journal of Research, 10,* 300–320.

Dunn, W. (1992). Occupational therapy collaborative consultation in schools. In E. G. Jaffe & C. F. Epstein (Eds.), *Occupational therapy consultation: Theory, principles, and practice* (pp. 210–236). St. Louis, MO: Mosby.

Dunn, W., Cox, J., Foster, L., Mische-Lawson, L., & Tanquary, J. (2012). Impact of a contextual intervention on child participation and parent competence among children with autism spectrum disorders: A pretest-posttest repeated-measures design. *American Journal of Occupational Therapy, 66*(5), 520–528. doi:10.5014/ajot.2012.004119

Dunstan, E., & Griffiths, S. (2008). Sensory strategies: Practical support to empower families. *New Zealand Journal of Occupational Therapy, 55*(1), 5–13.

Evered, R. D., & Selman, J. C. (1989). Coaching and the art of management. *Organizational Dynamics, 12*(5), 16–30.

Fertel-Daly, D., Bedell, G., & Hinojosa, J. (2001). Effects of a weighted vest on attention to task and self-stimulatory behaviors in preschoolers with pervasive developmental disorders. *American Journal of Occupational Therapy, 55*(6), 629–640. doi:10.5014/ajot.55.6.629

Graham, F., Rodger, S., & Ziviani, J. (2009). Coaching parents to enable children's participation: An approach for working with parents and their children. *Australian Occupational Therapy Journal, 56,* 16–23.

Graham, F., Rodger, S., & Ziviani, J. (2010). Enabling occupational performance of children through coaching parents: Three case reports. *Physical & Occupational Therapy in Pediatrics, 30*(1), 4–15. doi:10.3109/01942630903337536

Graham, F., Rodger, S., & Ziviani, J. (2013). Effectiveness of occupational performance coaching in improving children's and mothers' performance and mothers' self-competence. *American Journal of Occupational Therapy, 67*(1), 10–18. doi:10.5014/ajot.2013.004648

Graham, F., Rodger, S., & Ziviani, J. (2014). Mothers' experiences of engaging in occupational performance coaching. *British Journal of Occupational Therapy, 77,* 189–197. doi:10.4276/030802214X13968769797791

Hanft, B. E., & Pilkington, K.O. (2000). Therapy in natural environments: The means or end goal for early intervention? *Infants and Young Children, 12*(4), 1–13.

Hanft, B. E., & Place, P. A. (1996). *The consulting therapist: A guide for OTs and PTs in schools*. San Antonio, TX: Therapy Skill Builders.

Hanft, B. E., Rush, D. D., & Shelden, M. L. (2004). *Coaching families and colleagues in early childhood*. Baltimore, MD: Paul H. Brookes.

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. (2011a). Effects of weighted vests on classroom behavior for children with autism and cognitive impairments. *Research in Autism Spectrum Disorders, 5*(1), 495–505. doi:10.1016/j.rasd.2010.06.015

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. E. (2011b). Weighted vests, stereotyped behaviors and arousal in children with autism. *Journal of Autism & Developmental Disorders, 41*(6), 805–814. doi:10.1007/s10803-010-1104-x

Jaffe, E. G., & Epstein, C. F. (1992). *Occupational therapy consultation: Theory, principles, and practice*. St. Louis, MO: Mosby.

Joosten, A. V., Bundy, A. C., & Einfeld, S. L. (2012). Context influences the motivation for stereotypic and repetitive behaviour in children diagnosed with intellectual disability with and without autism. *Journal of Applied Research in Intellectual Disabilities, 25,* 262–270.

Kadar, M., McDonald, R., & Lentin, P. (2012). Evidence-based practice in occupational therapy services for children with autism spectrum disorders in Victoria, Australia. *Australian Occupational Therapy Journal, 59*(4), 284–293. doi:10.1111/j.1440-1630.2012.01015.x

Kielhofner, G. (2009). *Conceptual foundations of OT practice* (4th ed.). Philadelphia, PA: F. A. Davis.

Kientz, M., & Dunn, W. (2012). Evaluating the effectiveness of contextual intervention for adolescents with autism spectrum disorders. *Journal of Occupational Therapy, Schools, & Early Intervention, 5*(3-4), 196–208. doi:10.1080/19411243.2012.737271

Leew, S. V., Stein, N. G., & Gibbard, W. B. (2010). Weighted vests' effect on social attention for toddlers with autism spectrum disorders. *Canadian Journal of Occupational Therapy, 77*(2), 113–124. doi:10.2182/cjot.2010.77.2.7

Mattingly, C. F., & Fleming, M. H. (1994). *Clinical reasoning: Forms of inquiry in a therapeutic practice*. Philadelphia, PA: F. A. Davis.

Murdock, L. C., Dantzler, J. A., Walker, A. N., & Wood, L. B. (2014). The effect of a platform swing on the independent work behaviors of children with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities, 29*(1), 50–61. doi:10.1177/1088357613509838

Niehues, A. N., Bundy, A. C., Mattingly, C. F., & Lawlor, M. C. (1991). Making a difference: Occupational therapy in public schools. *Occupational Therapy Journal of Research, 11,* 195–209.

Olson, L. J., & Moulton, H. J. (2004a). Occupational therapists' reported experiences using weighted vests with children with specific developmental disorders. *Occupational Therapy International, 11*(1), 52–66. doi:10.1002/oti.197

Olson, L. J., & Moulton, H. J. (2004b). Use of weighted vests in pediatric occupational therapy practice. *Physical and Occupational Therapy in Pediatrics, 24*(3), 45–60. doi:10.1300/J006v24n03_04

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61*(2), 216–227. doi:10.5014/ajot.61.2.216

Parham, L. D., Roley, S. S., May-Benson, T. A., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a fidelity measure for research on the effectiveness of the Ayres Sensory Integration intervention. *American Journal of Occupational Therapy, 65*(2), 133–142. doi:10.5014/ajot.2011.000745

Quigley, S. P., Peterson, L., Frieder, J. E., & Peterson, S. (2011). Effects of a weighted vest on problem behaviors during functional analyses in children with pervasive developmental disorders. *Research in Autism Spectrum Disorders, 5*(1), 529–538. doi:10.1016/j.rasd.2010.06.019

Reichow, B., Barton, E. E., Sewell, J. N., Good, L., & Wolery, M. (2010). Effects of weighted vests on the engagement of children with developmental delays and autism. *Focus on Autism and Other Developmental Disabilities, 25*(1), 3–11. doi:10.1177/1088357609353751

Rodger, S., Ashburner, J., Cartmill, L., & Bourke-Taylor, H. (2010). Helping children with autism spectrum disorders and their families: Are we losing our occupation-centred focus? *Australian Occupational Therapy Journal, 57*(4), 276–280. doi:10.1111/j.1440-1630.2010.00877.x

Rodger, S., Ashburner, J., & Hinder, E. (2012). Sensory interventions for children: Where does our profession stand? *Australian Occupational Therapy Journal, 59*(5), 337–338. doi:10.1111/j.1440-1630.2012.01032.x

Rush, D. D., & Shelden, M. L. (2011). *The early childhood coaching handbook*. Baltimore, MD: Paul H. Brookes.

Schein, E. H. (1999). *Process consultation revisited: Building a helping relationship*. Menlo Park, CA: Addison-Wesley.

Schilling, D. L., & Schwartz, I. S. (2004). Alternative seating for young children with autism spectrum disorder: Effects on classroom behaviour. *Journal of Autism and Developmental Disorders, 34*(4), 423–432. doi:10.1023/B:JADD.0000037418.48587.f4

Schön, D. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner*. San Francisco, CA: Jossey-Bass.

Scott, S. (1997). Comparison of service delivery models influencing teachers' use of assistive technology for students with severe disabilities. *Occupational Therapy in Health Care, 11,* 61–74.

Simpson, D. (2015). Coaching as a family-centred, occupational therapy intervention for autism: A literature review. *Journal of Occupational Therapy, Schools, & Early Intervention, 8*(2), 109–125. doi:10.1080/19411243.2015.1040941

Sniezyk, C. J., & Zane, T. L. (2015). Investigating the effects of sensory integration therapy in decreasing stereotypy. *Focus on Autism and Other Developmental Disabilities, 30*(1), 13–22. doi:10.1177/1088357614525663

Thompson, R. M., & Johnston, S. (2013). Use of social stories to improve self-regulation in children with autism spectrum disorders. *Physical and Occupational Therapy in Pediatrics, 33*(3), 271–284. doi:10.3109/01942638.2013.768322

Toll, C. A. (2005). *The literacy coach's survival guide*. Newark, DE: International Reading Association.

Tomchek, S. D., & Case-Smith, J. (2009). *Occupational therapy practice guidelines for children and adolescents with autism*. Bethesda, MD: AOTA Press.

Tomlin, G. S., & Swinth, Y. (2015). Contribution of qualitative research to evidence in practice for people with autism spectrum disorder. *American Journal of Occupational Therapy, 69*(5), 1–4. doi:10.5014/ajot.2015.017988

Watling, R., & Hauer, S. (2015). Effectiveness of Ayres Sensory Integration® and sensory-based interventions for people with autism spectrum disorder: A systematic review. *American Journal of Occupational Therapy, 69,* 6905180030. doi:10.5014/ajot.2015.018051

Wilbarger, J., & Wilbarger, P. (2002a). Clinical application of the sensory diet. In A. Bundy, S. Lane, & E. Murray (Eds.), *Sensory integration theory and practice* (2nd ed.). Philadelphia, PA: F. A. Davis Company.

Wilbarger, J., & Wilbarger, P. (2002b). The Wilbarger approach to treating sensory defensiveness. In A. Bundy, S. Lane, & E. Murray (Eds.), *Sensory integration theory and practice* (pp. 335–338). Philadelphia, PA: F. A. Davis Company.

Wilbarger, P., & Wilbarger, J. (1991). *Sensory defensiveness in children aged 2–12: An* *intervention guide for parents and other caretakers*. Denver, CO: Avanti Educational Programs.

Williams, M. S., & Shellenberger, S. (1996). *How does your engine run? A leader's guide to the Alert Program for self-regulation*. Albuquerque, NM: TherapyWorks, INC.

Woronko, D., & Killoran, I. (2011). Creating inclusive environments for children with autism. In T. Williams (Ed.), *Autism spectrum disorders–From genes to environment:* InTechOpen. Retrieved from http://www.intechopen.com/books/autism-spectrum-disorders-from-genes-to-environment/creating-inclusive-environments-for-children-with-autism. London, UK. doi:10.5772/21136

APPENDIX 17-A

Part I: Strategies and Activities for Addressing Common School Problems

The following pages contain several activities and strategies that may be offered in the context of coaching interventions at school to address problems commonly experienced by children with sensory integrative dysfunction. These activities by no means represent an exhaustive list. In each case, a problem is listed along with its possible relationship to SI theory. Of course, all the difficulties that children with SI dysfunction experience are not caused by the sensory integration dysfunction.

We grouped the problems in Part I into categories. The categories, in the order in which they appear, are as follows:

- Writing
- Art and Construction
- Homework
- Distractibility
- Social Behavior
- Lockers and Desks
- Posture
- Miscellaneous

	PROBLEM	POSSIBLE RELATION TO SENSORY INTEGRATION THEORY	POSSIBLE STRATEGIES
WRITING	Child has a "death grip" on pencil.	Poor proprioception resulting in poor modulation of force	• Wrap the pencil or pen in stiff clay, which provides feedback to the child; if the clay is misshapen after the child uses it, the child's grip is too firm.
		Poor posture, which encourages forceful use of hands and arms	• Tilt the writing surface to help the child maintain a more upright posture, while also making it easier for the child to use appropriate force.
	Child uses so little pressure on pen that writing is almost illegible.	Poor proprioceptive processing resulting in poor modulation of force	• Have the child place paper atop a magic slate and press hard enough that the writing appears on the slate. • Have the child use a pencil with very soft lead or a felt-tip marker.
	Child can't copy accurately from board onto paper.	Poor oculomotor control resulting in difficulty switching from vertical to horizontal plane when copying	• Have the child copy from a book or paper to another paper in the same plane instead of from the board to the paper. • Have the child write on a slant-top surface, which reduces the change in angle from one surface to another.
	Child can't keep columns lined on arithmetic papers, so he or she always gets the wrong answer.	This problem may have many causes, including poor oculomotor control.	• Provide the child with grid or graph paper in which only one digit is allowed per space.

	PROBLEM	POSSIBLE RELATION TO SENSORY INTEGRATION THEORY	POSSIBLE STRATEGIES
WRITING	Child has difficulty forming letters or shapes.	Poor visual motor coordination	• Place a piece of clear plexiglass in a stand; someone sitting behind the plexiglass can draw letters backward for tracing on the other side; when the child is finished tracing, erase the lines on the other side, leaving only the child's work. A Magnadoodle can be used in a similar way; after the child traces the outline, erase the adult's markings.
	Letters vary markedly in size.	Poor visual motor coordination	• Use paper with raised lines (often available for children who are partially sighted).
ART AND CONSTRUCTION	Child refuses to use paste because he or she can't stand the feel of it drying on his or her skin.	Tactile defensiveness	• Have the child use a glue stick, glue in a bottle, a stapler, or Scotch tape instead of paste. • Have the child use a Popsicle stick instead of his or her fingers to spread the paste. • Place a container of wipes on the desk for the child to wipe off his or her fingers right away. • If the task is to glue the correct answer to the paper, allow the child to use another method of demonstrating knowledge (e.g., writing the correct answer).
	Child cannot cut with regular scissors.	Poor bilateral integration	• Fasten loop scissors to a small board and then fasten that to the top of the child's desk; the child can cut by pushing down with one hand and then turning and moving the paper with the other; this significantly reduces the bilateral demand.
HOMEWORK	Child forgets to take home the books or information needed for homework.	Poor organization	• As assignments are given, have the child place needed supplies into his or her backpack. Alternatively, create magnets or other manipulatives with words or pictures of needed books; as an assignment is given, have the child place the relevant icon in the same place; at the end of the day, the magnets remind the child which books to take home. • Have the student keep a second full set of books at home. • The teacher or a designated student creates an ongoing assignment list on the chalkboard, which includes the necessary books and materials.
DISTRACTIBILITY	Child follows instructions given to every child in the classroom because he or she is unable to screen out stimuli.	Distractibility secondary to sensory defensiveness (of course, there are many other causes of distractibility)	• Have the child sit in the least distracting area of the classroom, probably in a back corner. • Provide the child with written directions as well as verbal; make him or her responsible for checking the instructions himself or herself. • Provide an area in the classroom, such as a loft or quiet space (e.g., refrigerator box lined with carpet), where children can go when they feel they need a quiet place to work. • Some children find that wearing headsets helps cut down the amount of auditory stimulation coming in; also, some children find the weight of the headset to be calming.

Continued

	PROBLEM	POSSIBLE RELATION TO SENSORY INTEGRATION THEORY	POSSIBLE STRATEGIES
DISTRACTIBILITY	Child wanders around and disrupts classmates when he or she gets overstimulated or tired.	Distractibility secondary to poor sensory modulation (of course, there are many other causes of distractibility—see another explanation in the row that follows).	• Reduce the amount of stimuli. • Have the child sit in the least distracting area of the classroom, usually a back corner. • Help the child organize his or her workspace so he or she does not have to expend a lot of energy finding things. • Decrease bright lights and clutter, and provide a "cove" for the child's desk or a quiet space where the child can go to regroup.
	Child wanders around and disrupts classmates when he or she gets overstimulated or tired.	Some children who have motor planning problems fatigue easily with the motor demands of school; they also may wander aimlessly when tired.	• Build in many opportunities for the child to get up and move around during the day. • Have the child help out with "chores" around the classroom; if these provide increased proprioception through resistance to movement, all the better (e.g., banging erasers, washing the blackboard, carrying books to the office). • Provide the child with clay or "fidget toys" to use at his or her desk; this will give the child something to do but help keep him or her from disrupting others.
SOCIAL BEHAVIOR	Child pushes other children who come too close to his or her desk.	Fight-or-flight reaction secondary to sensory defensiveness	• Put the child's desk in the area of the classroom where there is the least amount of activity (usually a back corner), and provide a quiet space in the classroom where all children can go when they need to be alone (e.g., refrigerator box, loft). • At the appropriate time, discuss the problem with the child; help the child understand that he or she reacts differently than other kids to touch and noise; ask for the child's ideas and solutions and give alternative explanations for the other children's behavior (e.g., "Other children often come very close to you because they are your friends and feel comfortable with you"). • Help the child develop strategies for acceptable replacement behaviors to be used when he or she wants to hit (e.g., pull on a bungee cord attached to a belt loop or the desk). • Teach the whole class about the importance of respecting others' personal space and individual differences about comfort level in being close to others.
	Child gets too close to other children when he or she is playing and during circle time.	This problem, which sometimes seems related to knowledge of the boundaries of the body, is not usually seen in children with sensory integrative dysfunction; however, it is a complicated problem and not clearly associated with any aspect of SI theory.	• Because the problem seems related to a lack of internal sense of boundaries, provide the child with external guides to help him or her stay out of others' personal space. • During circle time, allow the child to choose a stuffed animal that he or she is responsible for; the animal requires being held firmly throughout the circle time activity. • Begin circle time by explaining that everyone needs to be at arm's length away from each other; after the correct distance is established, provide carpet squares or hula hoops for children to sit on or in; the hook side of Velcro also can be used to form a stationary, but readily removed, square. • During playtime, engage the child in games that promote being in contact with other classmates, such as steamroller; point out that this game is intended for being close but that most other games are not.

	PROBLEM	POSSIBLE RELATION TO SENSORY INTEGRATION THEORY	POSSIBLE STRATEGIES
LOCKERS AND DESKS	Child's desk is so disorganized that he or she cannot find anything.	Disorganization is commonly associated with dyspraxia.	• Line the child's desk with butcher paper; outline and label the places where the folders, pens, books, and so on, should go. • Attach small boxes to the desk floor for various objects. • Give the child a colored folder for each subject; require that the child take time after a subject is completed to put supplies away before the next subject is started. • If the child feels rushed and then stuffs things into the desk, give the child a timer to set or give verbal reminders so he or she can anticipate when an activity will end and can put things away properly.
POSTURE	Child slouches in seat or falls out of seat.	Decreased postural control secondary to poor processing of vestibular-proprioceptive information; this problem is often accompanied by poor ability to cross the midline while doing desk work; child moves nearer to the edge of the chair and is at risk for falling, especially if he or she does not have a good sense of the vertical.	• Allow the child or class to lie or sit on the floor during some activities; wedges, pillows, and beanbag chairs can make this more appealing. Slanting the table surface makes it easier for the child to maintain good posture and may decrease incidences of falling. • Some therapists have been successful having children sit on t-stools; they believe that the children must pay closer attention to their posture and, therefore, remain more erect. • Make sure the child's feet touch the floor; if they do not, a footrest slanted toward the child may help. • Apply a nonslip surface to the seat of the chair (e.g., Dycem, bathtub decals).
MISCELLANEOUS	Student misses recess because he or she can't complete assignments on time; the child really needs recess to "let off steam."	There are many reasons why a child may fail to finish work on time; two that are related to SI theory are distractibility secondary to sensory defensiveness (which makes it difficult to focus) and poor motor planning (which makes it difficult to get large quantities of work done); in either case, periodic opportunities to be active can help the child get more done.	• Provide as many opportunities as possible for active work during the day; for example, instead of sitting at his or her desk while doing math, have the child do math problems on the board. • If the problem is with the quantity of work, see if the teacher would consider shortening in-class assignments; for example, how many problems does the child have to do correctly to demonstrate that he or she has mastered the concept of adding two-place numbers? • Break assignments into two parts, and allow the child to work on them in smaller segments.

Continued

	PROBLEM	POSSIBLE RELATION TO SENSORY INTEGRATION THEORY	POSSIBLE STRATEGIES
MISCELLANEOUS	Child chews collars of clothing or hair when stressed, which is frequently; he or she is ruining clothes and smells bad much of the time.	Stress is not unusual among children who have sensory integrative dysfunction, both children with dyspraxia and with modulation disorders.	• Teach stress-reduction strategies to the whole class (e.g., pet a stuffed animal, listen to rain on a personal stereo, find a safe space to regroup). • Provide replacements for hair or clothing (e.g., a length of knotted tubing, an object at the end of a pencil, sugar-free gum); some children seem to thrive on oral stimulation; rather than (or in addition to) chewing, they might enjoy blowing on whistles (with the noise maker removed) or blowing into Theraband© stretched tight across the face to produce a "raspberry" noise.
	Student gets lost going from the classroom to other destinations in school.	A poor sense of real space is common to many children who have sensory integrative dysfunction. Neuroscience literature links poor vestibular processing with poor spatial navigation by way of vestibular projections to the hippocampus.	• Have the child take a buddy with him or her. • Create colored lines along the walls going to common destinations (e.g., office, bathroom, lunchroom).

APPENDIX **17-A**

Part II: Selected Activities to Address Underlying Aspects of Sensory Integrative Dysfunction

Note: The activities listed in the text that follows are different from those in Part I in that they are meant to address aspects of the underlying problem that prevents a child from accomplishing certain school tasks. This is by no means an exhaustive list of activities. Be aware that the more the activity clearly seems related to a particular school problem, the more likely a teacher is to incorporate it into the day's routine.

Activities that Provide Enhanced Proprioception

- Use a vibrating pen that changes oscillations as the pressure on the pen changes.
- Do graphite or crayon "rubbings" of three-dimensional objects (e.g., leaves).
- Use media that encourage the child to pull and work his or her hands and fingers, such as putty, play dough, clay, or rubber bands.
- Use activities that encourage the child to push, pull, or carry heavy loads, such as stacking chairs, carrying books to the office, or collecting all the blocks on the floor into a large box.
- Allow the child to lie supine under a small table and write against the underneath surface of the table. Some children even enjoy bracing their feet against the bottom of the table surface. Of course, that probably means someone will have to sit on the table to keep it from going up in the air.
- Provide the child with a balloon filled with flour or gel to fidget with as he or she listens. Hearthsong of California (1-800-325-2502) makes stress balls shaped to resemble animals for squeezing.

Activities that Provide Enhanced Tactile Sensation (Especially Deep Pressure)

- Fill the tub with beans or rice, and hide familiar objects in the beans or rice. Have the child search for the objects by touch.
- Fasten a textured substance (e.g., carpet square or object such as a surgical brush) on top of or underneath a desk surface. Encourage the child to rub his or her hands briskly across it before engaging in activity.
- Techniques such as wrapping the child tightly in a blanket and also rocking or sitting on the teacher's lap during story time (as tolerated) can provide deep pressure under certain circumstances.

Activities that Provide Enhanced Vestibular Sensation

- Use movement activities, especially activities that involve swinging or jumping, and many playground activities.
- Encourage the child to rock in a rocking chair before a new activity is started or during the activity.

- Some children work well sitting on a gymnastic ball or other surface on which they can bounce and move around. Stabilize the ball in a cardboard box or small square wooden frame.

Activities that Require Modulation of Force

- Use the Hungry-Hippo game. This requires the correct amount of pressure to shoot the hippos into the correct spot.
- Play the Operation game or simply pick up any small objects with tweezers; this requires deft prehension and modulation of force. Do the egg, water balloon, or shaving cream ball toss. Catching, especially, requires modulation of force so as not to break the object.

Suggestions for Tactile Defensiveness

- Do activities that provide light, unexpected, or noxious touch when a child is relatively calm.
- Provide a quiet place for the child to engage in tactile activities.
- Create loft areas or refrigerator boxes placed in a corner of the room where any child can go when he or she feels a need to be in a quiet place.
- Have a child prepare for an activity by having a little quiet time.
- Provide a child with a box to sit on his or her desk into which he or she can insert his or her head. The box is painted a dark color on the inside and the outside and has a curtain across the open side. Glow-in-the-dark stars can be attached to the inside walls of the box. The child uses a flashlight to illuminate the stars and is then allowed to stay in the box until the stars stop glowing.
- Any activity that provides deep pressure input may be useful before engaging in an activity that may “aggravate” a child’s tactile defensiveness.

CHAPTER 18

Complementary Programs for Intervention

Julia Wilbarger, PhD, OTR/L ■ Patricia Wilbarger, MED, OTR/L, FAOTA ■ MarySue Williams, OTR/L ■ Sherry Shellenberger, OTR/L ■ Molly McEwen, MHS, OTR/L ■ Gudrun Gjesing ■ Beth Osten, MS, OTR/L ■ Mary Kawar, MS, OT/L ■ Sheila Frick, OTR/L ■ Patricia Oetter, MA, OTR/L, FAOTA ■ Eileen W. Richter, MOH, OTR/L, FAOTA

If something is complementary, then it somehow completes or enhances the qualities of something else.

— https://www.vocabulary.com/dictionary/complementary

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Have a broad understanding of the background and basis of several sensory-based therapeutic approaches currently used to complement sensory integration (SI) intervention.
- ✔ Understand suggested links between SI and these complementary approaches.
- ✔ Describe expected therapeutic benefits in application of these approaches.
- ✔ Be able to appraise the application of these approaches based on characteristics of children and adults for whom these approaches are intended.

Introduction

SI theory has inspired several occupational therapists to develop or adopt intervention programs and applications that complement the theory in some way. Such programs and applications are often used alongside interventions drawn directly from the theory. We invited several occupational therapists who are well known for their contributions to professional development and the creation or implementation of innovative complementary programs to contribute to this chapter. Aspects of SI theory, most commonly enhanced sensation, are inherent to all these programs and applications. However, each differs in some important way from "pure" sensory integrative therapy. Giving voice and venue to these professionals offers readers an opportunity to learn about and evaluate complementary programs and applications commonly used with children and adults who have sensory integrative dysfunction. Readers should be aware that, although these are in common usage, all are in need of empirical research to examine their effectiveness, appropriateness, and feasibility.

Based on Ayres' teaching and writing, we define intervention based on the principles of SI as:

> thoughtful provision of opportunities to actively (1) take in enhanced tactile, vestibular and proprioception sensations in the context of (2) engagement in meaningful activity (generally play) that promotes postural development, praxis, sensory modulation, and self-regulation.

Both components must be present for an intervention to be considered SI. The relative importance of particular sensations and outcomes for any given child is determined through comprehensive assessment.

Three Areas of Sensory Integration

We used the definition of SI in the preceding section to set the context for evaluating each of the programs in terms of the extent to which each overlapped with, or complemented, intervention based on the principles of SI. In the table that precedes each section, we analyzed the program in three areas:

1. Sensation(s) emphasized—Is the sensation embedded within the program uni-modal or multi-modal? Does the program emphasize integration of sensations? Does the child take in sensation actively or passively?
2. Approach—Is program implementation varied (i.e., responsive to the child's needs at the time) or prescribed (i.e., standardized)?
3. Setting—In what setting is the intervention typically administered (i.e., traditional [clinic] vs. nontraditional [home, school, community])?

Sensation

Providing opportunities to *actively* integrate sensation in the context of a demand for an adaptive response is a principle tenet of SI theory. "Integration is achieved by organizing and emitting an adaptive response, and therapy is achieved when that response represents more complex organization than previously accomplished" (Ayres, 1972, p. 36). Although some of the programs and applications described in this chapter adhere to this principle, others focus on receiving, rather than actively taking in, sensation. This is done through passive application of sensation, seemingly to ensure ample stimulation and control the characteristics of the stimulation (e.g., intensity and duration).

In her teaching and writing, Ayres (1972, 1979) emphasized the *integration* of three types of sensation: vestibular, tactile, and proprioceptive. These proximal senses develop early in life and seem to serve as points of reference for the distal senses of vision and hearing, which develop later. Perhaps Ayres would have examined the distal senses more fully had she lived longer. Certainly, she never excluded, or downplayed the importance of, any sensation. (See also Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited.) Many of the programs described here emphasize senses other than vestibular, tactile, and proprioception. Some emphasize integration, whereas others focus on particular sensations.

Approach

Ayres described therapy in much the same way that many authors describe play: as constantly evolving and determined by the "player" (i.e., the recipient of the services, as described in Chapter 12, The Art of Therapy). Nonetheless, in an attempt to make intervention "systematic," some of the interventions described in this chapter involve prescribing the type, application, and dosage of sensation; they appear to lack the spontaneity that Ayres described. Others are more varied and responsive to a child's needs at the time. Clearly there are both advantages and disadvantages to each approach.

Setting

Ayres wrote solely about therapy implemented in clinic settings. Perhaps this was simply a reflection of the time during which she was practicing and writing: at that time, intervention occurred in the clinic. Or perhaps, the clinic represented a space where numerous opportunities for taking in sensation and acting on challenges were presented reliably. Times have changed and, although the clinic remains an important site for therapy, the press for family-centered interventions means that an increasing number of interventions are integrated into everyday activity at home, in school, and in other community settings. (See also Chapter 17, Using Sensory Integration Theory in Coaching.) The authors in this chapter present interventions that take place in the whole gamut of sites, from the clinic to the swimming pool.

Purpose and Scope

Readers will learn about a range of programs and applications in this chapter. We introduce each section with a table summarizing Sensations Prioritized, Approach, and Setting. In examining programs from these three perspectives, we seek only to inform, not to present conclusions regarding effectiveness, appropriateness, or feasibility. Readers should decide which of these approaches fits their practice and the children and families they serve.

Although none of the programs discussed here meets all the requirements for intervention based on the principles of SI theory, as outlined previously, individuals with sensory integrative dysfunction *may* benefit from any of them, when used judiciously. In an effort to keep this chapter manageable in scope, we have included only eight of a myriad of complementary interventions. The programs and applications reviewed in this chapter are:

- Section 1: The Wilbarger Approach to Treating Sensory Defensiveness (by Julia Wilbarger & Patricia Wilbarger)
- Section 2: The Alert Program® for Self-Regulation (by MarySue Williams, Sherry Shellenberger, & Molly McEwen)
- Section 3: Aquatic Therapy (by Gudrun Gjesing)
- Section 4: Interactive Metronome® (by Beth Osten)
- Section 5: Astronaut Training Program (by Mary Kawar)
- Section 6: Infinity Walk Training (by Mary Kawar)
- Section 7: Therapeutic Listening® (by Sheila Frick)
- Section 8: Applying Suck/Swallow/Breathe Synchrony Strategies to Sensory Integration Therapy (by Patricia Oetter & Eileen Richter)

For each complementary program, authors described the following:

- The background to the program
- The rationale for why the program is thought to work and the associated evidence—both as it exists and what is needed
- Description of program components, and the way it is carried out
- The relationship of the program to SI theory and occupation
- Benefits expected and most commonly attained, based in research and clinical experience
- Populations for whom the approach is appropriate
- Training recommended or required
- A case example or short vignettes of individual(s) who benefitted from the approach

Each author provided references related to the individual programs discussed; the references appear by section at the end of the chapter. In some cases, the rationale provided or terminology used by the authors is different from the information or terminology used elsewhere in this book. To provide the most accurate description, whenever possible, we have preserved the authors' terminology.

Readers are asked to consider carefully the evidence for each program and evaluate what is most useful for individual children. SI represents a *theory;* the theory will expand only because of discussion among knowledgeable clinicians and theorists. Certainly, Ayres would have wanted her theory to grow.

Section 1: The Wilbarger Approach to Treating Sensory Defensiveness

Julia Wilbarger, PhD, OTR/L ■ Patricia Wilbarger, MED, OTR/L, FAOTA

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. multi- vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional or both
Wilbarger Approach (Three Components)			
1. Education	NA	NA	NA
2. Sensory diet	• Integrated • Active	• Prescribed	• Nontraditional
3. Therapressure	• Multisystem • Passive	• Prescribed	• Both

Background

Sensory defensiveness is a constellation of symptoms that involve negative, aversive, or avoidant responses to non-noxious sensation across all sensory modalities (Wilbarger & Wilbarger, 1991). Sensory defensiveness can constrain function and adaptation in all areas of occupational performance and throughout the entire life span. Wilbarger and Wilbarger (1991) argued that sensory defensiveness is so disruptive to an individual's life that it should be a primary concern in intervention. At the core, sensory defensiveness is a disruption in the ability to modulate responses to sensation not only in terms of increased reactivity (Reynolds & Lane, 2008) but also in the production of negative affect (Ayres, 1972); thus, it cannot be thought of as simply an over-responsiveness to sensation (see Chapter 6, Sensory Modulation Functions and Disorders).

The Wilbarger approach to treating sensory defensiveness is a comprehensive, intensive, and individualized program to reduce sensory defensive symptoms (Wilbarger & Wilbarger, 1991). The approach involves prescribed sensory experiences repeated frequently during a short period of time. Wilbarger was strongly influenced by Ayres (1972, 1979), but the Wilbarger approach has evolved during the past five decades, guided by the study of functional neurology, collaboration with colleagues, and experience in clinical practice.

Rationale

Many of the symptoms of sensory defensiveness suggest a disruption in a central nervous system (CNS) process that evaluates incoming stimuli for positive or negative valence (LeDoux, 1996, 2014; Pribram, 1991; Rolls, 2014). This process has been referred to, or described as, the *protocritic system* by Pribram (1991), *low route* processing by LeDoux (1996), and the *evaluative system* by Rolls (2014). In general, this evaluative system is responsible for the rapid, automatic, and subconscious evaluation of the affective qualities of stimuli. The evaluative process also affects and is affected by CNS structures related to emotions, memory, autonomic arousal, and adaptation to stress. One function of this evaluative system is to alert the individual to potential danger in the environment and initiate the appropriate behavioral and physiological defensive responses, including changes to the autonomic nervous system.

Sensory defensiveness is believed to be a disruption in the evaluation of sensory stimuli that results in defense responses. In fact, the behavioral and physiological responses of individuals with sensory defensiveness to certain kinds of sensation are nearly identical to those produced by fear or stress stimuli, including, but not limited to, increased levels of sympathetic arousal and poor habituation (Reynolds & Lane, 2008). Stimuli that are most likely to produce sensory defensive responses have features in common with stimuli that naturally trigger general defensive responses (LeDoux, 2014). For example, light tactile input and high frequency noises share sensory features with a spider crawling on the skin and a distress cry of an infant or an animal in pain. A person with sensory defensiveness may be more sensitive to sensations with these types of alarming features. Therefore, sensory defensive responses may lead to changes in arousal, affective tone, and stress and produce a wide range of functional difficulties.

The rationale for Wilbarger's intervention approach is based on the assumption that certain types of sensory experiences are thought to be effective for reducing sensory defensive responses (Ayres, 1972, 1979; Wilbarger & Wilbarger, 1991). These include deep pressure, proprioception (i.e., muscle resistance, joint traction, and compression), and vestibular input (Ayres, 1972, 1979). These types of sensation are believed to influence the adaptation to and modulation of environmental sensory input along with resultant physiological responses (Field, 2010; Ornstien & Sobel, 1987; Pribram, 1991). Presumably, the ultimate effectiveness is mediated by the global integrative effects these inputs have on the CNS.

Somatosensory input is a powerful agent for improving well-being and reducing stress and pain (Field, 2011; Hertenstein & Weiss, 2011). Repeated application of sensory input is believed to facilitate homeostasis and regulation of behavior in much the same way that massage and other intense somatosensory-based interventions (e.g., transcutaneous electrical nerve stimulation [TENS] and acupuncture) reduce chronic pain (Deer & Leong, 2012). Long-term adaptation likely takes place at the biochemical, cellular, and behavioral levels (Field, 2010; Pert, 1997).

Program Description

Sensory defensiveness is a difficult condition to treat. Individuals with sensory defensiveness are often resistant to novelty and change and accept only a narrow range of sensory experiences. The introduction of sensory-based interventions needs to be carefully considered and planned. The Wilbarger approach to treating sensory defensiveness involves a specific, individualized intervention program. The approach incorporates three essential components:

1. Education of the child and caregivers to promote awareness of the presence and impact of symptoms of sensory defensiveness
2. A sensory diet that incorporates sensory-based activities into daily routines
3. A professionally guided intervention program that involves very specific, individualized intervention with careful monitoring

Professionally guided intervention may or may not include the Therapressure Program™, sometimes called the Wilbarger protocol. (This procedure also has been referred to as "brushing," but this term does not accurately convey the intent of the technique and is misleading.) Although the scope of this section does not allow for a complete description of this program, we will highlight key features below.

Education

Educating children and their caregivers or family to understand the impact of sensory defensiveness on everyday life is, by itself, therapeutic. Education can provide an explanation for and awareness of previously incomprehensible reactions and feelings. Awareness allows children and their caregivers to reinterpret sensory defensive behaviors and recognize how they disrupt everyday life. Both knowledge and awareness emerge from the evaluation process. The evaluation process should result in a relatively comprehensive and prioritized list of behaviors related to sensory defensiveness, including (1) primary defensive responses to sensation in daily life,

(2) behaviors or disruptions secondary to sensory defensiveness, and (3) coping strategies (Kinnealey, Oliver, & Wilbarger, 1995). The "problem list" is the basis for intervention planning, monitoring, and assessment of outcomes. The primary assessment tool is a structured clinical interview. The use of standardized self-report or parent-report questionnaires such as the Sensory Profile-2 (Dunn, 2014) or Sensory Processing Measure (Parham, Ecker, Miller-Kuhaneck, Henry, & Glennon, 2007) can be helpful in identifying some behaviors related to sensory defensiveness but rarely provide a full profile of life disruptions.

Sensory Diet

The second aspect of intervention is a sensory diet. A **sensory diet** is a strategy for developing individualized home programs that are practical, carefully scheduled, and based on the concept that controlled sensory input can affect functional abilities. The sensory diet therapy plan involves the therapeutic use of sensation in the context of daily activities (Wilbarger, 1993) and is used to address sensory defensiveness in two different ways: (1) Activities with sensory qualities that are most likely to reduce defensive behaviors are identified and implemented in the course of daily life routines; and (2) Adaptations are made to the environment to promote optimum functioning and reduce disruption.

Sensory-based activities provided at regular intervals are the cornerstone of the sensory diet. The activities are chosen to emphasize sensory inputs such as deep pressure, proprioception, and movement (Ayres, 1972, 1979; Wilbarger & Wilbarger, 1991). Other strategies (e.g., oral and respiratory) also can be used, particularly for gaining and maintaining regulation of arousal states (Oetter, Richter, & Frick, 1995, Section 8; Williams & Shellenberger, 1994). In this program, it is important to keep in mind the power of a particular activity to produce adaptation and how long it may be expected to influence behavior. Activities can be brief and provide a specific type of sensory input, or adaptation can be achieved by engaging in play, leisure, or work activities.

The sensory diet also includes adaptations to the environment to promote optimum functioning and reduce disruption. For example, adaptations frequently are made to daily routines (e.g., dressing, bathing, and transitions) to reduce the distress and discomfort that often accompany them; these suggestions may include preparatory sensory activities or simply altering the routines in which these activities are done. In addition, caregivers are informed about ways to reduce sources of sensation in the environment (e.g., sounds, smells, and visual distraction) and develop consistent routines and predictability. These suggestions must be customized to match the challenges unique to each individual.

Professionally Guided Intervention

Professionally guided intervention involves assessment, development of goals and objectives, and formation of an intervention plan in collaboration with children and their caregivers. The professionally guided intervention program may include the therapeutic use of deep pressure and proprioception (Therapressure Program), but often includes recommendations for other advanced strategies. Strategies include but are not limited to direct individual intervention using a traditional sensory integrative approach or other complementary approaches such as sound-based therapies (e.g., Therapeutic Listening®, Frick & Young, 2009 [See Section 7]) and body work (e.g., Craniosacral Therapy [Upledger & Vredevoogd, 1983]). A variety of intervention strategies can be used to address certain complications or other conditions: overload or shutdown, oral defensiveness, postural problems, or disruptions in the suck-swallow-breathe synchrony (see Section 8). Referrals to other professionals, such as a psychologist, may be necessary to address social and emotional issues related to sensory defensiveness.

The Therapressure Program involves the use of a specific densely bristled brush, which, when used correctly, can deliver deep pressure evenly without friction, tickle, or scratch. The authors recommend only one brush for this program: the Therapressure Brush™ manufactured specifically for this purpose by Clipper Mills (San Bruno, CA). The Therapressure Brush is available through multiple vendors of SI materials and equipment.

Deep pressure is applied to the child's hands, arms, back, legs, and feet. The tactile input is never applied to the stomach, groin, buttocks,

FIGURE 18-1 Brushes, textured mitts, and joint compression. *Photo courtesy of Shay McAtee, printed with permission.*

head, or face. Deep pressure is always followed by compression of several joints in the trunk, arms, and legs (see Fig. 18-1). The provision of deep pressure and proprioception seems deceptively simple. However, the procedure cannot be conveyed adequately in written form. The authors' experience with training professionals and caregivers in this technique has revealed many misinterpretations of its application, particularly in the amount of pressure needed. Anyone executing the deep pressure and proprioceptive procedure described by Wilbarger should have specialized training or direct supervision from someone with such training.

This procedure must be repeated frequently. Ideally, deep pressure and joint compression are administered every 90 minutes to 2 hours. However, frequency and timing depend on the daily routines and unique needs of the child. Clinical experience has shown that lack of appropriate pressure or less frequent application not only reduces efficacy but may be detrimental. The duration and modification of the intervention plan is based on the child's progress. Furthermore, the program requires frequent (sometimes daily) evaluation of effectiveness. Modification and continuation of the plan are informed by the changing needs of the child. There is no specific time frame for the duration of intervention. Intervention continues until the child's goals are met.

Individuals with sensory defensiveness exhibit unique behaviors that complicate the use of sensory-based interventions. Because of sensory defensiveness, these individuals often avoid sensory experiences in general and novel activities in particular. Involving a child in a novel sensory experience (such as the Wilbarger protocol) requires skill and sound clinical reasoning. One must approach a child with sensory defensiveness positively and create as little anticipatory anxiety as possible; this might include describing what to expect using words or pictures or modeling the techniques on a doll or other person. Care must be taken to use the procedures correctly and appropriately.

Relationship to Sensory Integration and Occupation

The three parts of the Wilbarger approach to intervention with individuals with sensory defensiveness all draw, to varying degrees, on principles of SI theory and occupational therapy. *Education,* as previously described, is a way of using SI theory to reframe problematic behaviors associated with sensory defensiveness. *Sensory diets,* which include active engagement in self-selected or preferred sensory activities embedded in daily routines, represent a subset of the principles of SI theory (Parham, Cohn, et al., 2007). All *professionally guided interventions* must be evaluated individually for their relationship to SI theory. The Therapressure Program described previously involves enhanced sensation but does not demand an active response. Thus, it overlaps with some but not all principles of SI. All aspects of the Wilbarger approach are directed toward helping children achieve internal adaptation in order to improve the quality and effectiveness of overt adaptive responses. The ultimate aim is to contribute to improved occupational and role performance.

Expected Benefits

Clinical reports suggest the Wilbarger approach is successful for reducing sensory defensive responses in some people. The majority of evidence for the benefits of the approach comes from professional opinion or clinical reports. Published empirical research to date is limited and consists mainly of single case or small sample multiple case study designs (Weeks, Boshoff, & Stewart, 2012). Additionally, some research has been reported in conference presentations or in master's or doctoral theses (c.f., Chapparo & Mora, 2011; Sudore, 2001). Most of the studies report some positive outcomes. Informal surveys to therapists trained in the Wilbarger approach conducted by the authors indicate that about two-thirds of children are rated as making "very good" to "some" improvement in function. Similar findings are reported in an unpublished master's thesis (Sudore, 2001).

Various functional goals may be established when using the Wilbarger approach in research or practice, although the primary goal of the approach is to reduce sensory defensiveness. The positive outcomes reported in the published research include decreased sensory defensiveness, lowered stress or anxiety, reductions in the stress hormone cortisol, reduced stereotypical behavior, improved social engagement, and better breastfeeding (Bhopti & Brown, 2013; Davis, Durand, & Chan, 2011; Kimball et al., 2007; Weiss-Salinas & Williams, 2001).

With a few exceptions, the currently published research is methodologically weak, consisting of small samples, lacking control groups, and poorly adhering to intervention protocols in terms of including all components, frequency, and duration of application. As with any intervention, practitioners deciding whether to use the Wilbarger approach with children should consider evidence as part of their decision-making process; however, there are ways in which the approach should be conducted in order to achieve maximal short- and long-term benefits. For example, intervention to reduce sensory defensiveness must always occur within the context of a comprehensive intervention plan that considers all aspects of the individual's life. Intervention must be appropriate to the child's age, level of disability, context, and available social support. When these considerations are made, individuals with sensory defensiveness, without other significant problem areas, who are treated with the comprehensive application of all three components of the Wilbarger approach and consistently adhere to the program, are most likely to show improvement.

The Wilbarger approach, similar to all other programs or interventions, is not effective for all people. Research is needed to determine the population(s) for whom the approach will be most effective, including children and adults who have sensory defensiveness that co-occurs with other disorders or medical complications. Furthermore, intervention to reduce sensory defensiveness is not limited to the Wilbarger approach. Occupational therapists have been treating sensory defensiveness for decades using the principles of SI theory (Ayres, 1972, 1979). In general, expectations for effectiveness depend on the complexity of the individual's clinical picture, confounding problems, adequacy of the program, and faithful adherence to the program.

Target Populations

The Wilbarger approach was developed specifically to address sensory defensiveness, which appears to be present in many clinical conditions. The populations in the current research on the Wilbarger approach include not just children and adults with sensory processing disorders but also individuals with autism, developmental disabilities, and adults and adolescents with psychiatric disorders (Bhopti & Brown, 2013; Davis, Durand, & Chan, 2011; Moore & Henry, 2002; Pfeiffer & Kinnealey, 2003; Stratton & Gailfus, 1998; Withersty, Stout, Mogge, Nesland, & Allen, 2005). In most cases, it is not appropriate for use with individuals who have behavioral or health problems not accompanied by sensory defensiveness. The Therapressure Program should not be used on infants younger than 2 months of age (when age has been corrected for prematurity) or on individuals with autonomic, physiologic, or CNS instability. Medical histories, psychological status, and appropriate individual precautions should be considered in all cases.

Training Recommended or Required

Intervention for and management of sensory defensiveness require expertise gained by specific training through continuing education, mentoring, and advanced knowledge of sensory processing and sensory integrative theories. The Therapressure Program described here should not be used without direct training. The authors offer continuing education courses on intervention for sensory defensiveness using this approach. These courses are commonly advertised through occupational therapy newsletters and magazines. It is also recommended that therapists complete courses in SI theory.

CASE STUDY ▪ DANIELLE

Danielle's mother began to suspect that 9-year-old Danielle might have problems with sensory processing after a cousin was diagnosed with a sensory processing disorder. Interviews with Danielle and her mother revealed behaviors suggestive of significant defensiveness to tactile, auditory, visual, and olfactory sensations. Danielle's mother rated most of Danielle's problematic behaviors as moderately severe or disruptive and occurring daily. Danielle did not want anyone to help (touch) her with any self-care activities. She cried every time she had her hair brushed or cut. Danielle also complained frequently about the smells of self-care and cleaning products such as shampoo and laundry soap and reported these gave her headaches. She chose only soft cotton clothing and did not like elastic waist bands. She was a very picky eater, refusing some textures of food and, again, complaining about the smell of many foods. Danielle was affectionate with her parents but did not want anyone else to hug or kiss her. Her younger brother was particularly irritating because he would try to grab Danielle and would screech with laughter when she got upset. Danielle loved to play and particularly liked to swing and swim, but when playing outside she complained of the bright sunlight. This also gave her a headache, so she would not go out on bright days. She had trouble sleeping and only slept in a sleeping bag on the floor of her parents' room. No medical reason for the headaches could be identified and the occupational therapist evaluating Danielle suspected that they might be secondary to the sensory defensiveness.

After educating Danielle and her family about sensory defensiveness, Danielle was given an intervention program that consisted of the Therapressure Program administered eight times a day, approximately every 2 waking hours, and a sensory diet. As the program began in the summer, all activities were done by her parents. The Therapressure Program was scheduled to match the family's schedule, but generally took place at wake-up, after breakfast, mid-morning, before lunch, mid-afternoon, late afternoon, after dinner, and before bedtime. The main components of the sensory diet consisted of swinging on the family swing set and play wrestling with her parents. The swing set was adapted so that Danielle could swing in prone and pull a rope to propel herself. The swing set also had a set of rings. Hanging from the rings, she would swing to kick a beach ball with her mother. The play wrestling consisted of safe rough and tumble play with her parents. In this case, the emphasis was to be on all fours on the ground and push and roll over each other without using hands to maximize deep tactile pressure and proprioception. Before beginning, everyone needed to say "Start," and if anyone said "Stop," everyone needed to stop. These activities were to occur for at least 10 minutes at least four times a day. Other suggestions included using a straw to drink and manipulating a squishy stress ball in the car.

The family was asked to log the application of Therapressure as well as the occurrence of sensory defensive reactions daily and provide a note about daily behavior. During the first few weeks, the Therapressure was provided inconsistently, only two to three times a day. Danielle loved the sensory diet activities and these were done frequently and consistently. Nonetheless, little progress was noted. On the third week, the frequency of the Therapressure increased to at least six times a day, and progress was evident immediately. The first change was a dramatic decrease in the severity and frequency of the headaches, followed by a decrease in tactile symptoms. By the fourth week, she was trying new foods and allowing her mother to help her with her hair. She continued to improve during the next few weeks with the last area to diminish being sensitivity to smells. At the end of 6 weeks, Danielle's mother rated most of the symptoms as mild or of no concern and happening less than once a week. Danielle's mother noted the biggest accomplishment was that Danielle was able to sleep at a friend's house for the first time.

Section 2: The Alert Program® for Self-Regulation

MarySue Williams, OTR/L ■ Sherry Shellenberger, OTR/L ■ Molly McEwen, MHS, OTR/L, FAOTA

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
The Alert Program®	• Integrated • Active	Prescribed, but varies among children	Nontraditional

Background

For decades, the Alert Program® has provided an organizing framework and process for addressing issues of **self-regulation** for both children and adults. This approach is grounded in Ayres' (1972, 1979) theory of SI regarding issues of CNS arousal. The theory underlying the Alert Program® is that **arousal** "can be considered a state of the nervous system, describing how alert one feels," and self-regulation is "the ability to attain, maintain, and change one's arousal appropriately for a task or situation" (Williams & Shellenberger, 1996, pp. 1–5). The Alert Program® promotes awareness of the importance of self-regulation and encourages the use of sensorimotor strategies to manage arousal states to support optimal functioning. It has been utilized in more than 40 countries of the world.

The core of the Alert Program® was taught to Williams (co-author) by one of her "instructors," an 11-year-old child. The young girl entered the therapy clinic in a low state of alertness and appeared to be lethargic, disinterested, and resistant to activities or interactions. After a short period of active play using sensory integrative techniques, she became alert, communicative, confident, and energetic (i.e., in an optimal state of alertness for the given tasks).

The child struggled to find words to describe her inner experience of self-regulation and, therefore, was unable to generalize her therapeutic experience to home or school. Williams introduced an engine analogy by explaining to the child, “If your body is like a car engine, sometimes it runs on high, sometimes it runs on low, and sometimes it runs just right.” Her states of alertness were observed and identified using the engine analogy, “Hmmm, it looks like your engine is low right now. I can tell because you look a little droopy and are having trouble playing.” And when Williams observed a high state of alertness, she explained to the girl in a neutral tone of voice, “Looks like your engine is running pretty high right now. I can tell because you are talking and moving fast, and it’s getting hard for you to share your ideas so we can play together.”

Not only did Williams comment frequently about the child’s engine level, but she talked about her own adult “engine.” For example, she demonstrated a lethargic posture at the start of an early morning therapy session and said, “Gosh, my engine sure is in low this morning. I know I need to get up and get moving. Let’s go play into the therapy room together.” By modeling to the child, she reinforced how to identify “engine speeds” and began teaching the five ways to change alert levels: mouth, move, touch, look, and listen.

With Williams’ verbal reflections and observations, the child learned about her own unique nervous system and developed a repertoire of effective “engine strategies.” Together, they developed sensory routines and problem-solved how to insert more “engine strategies” throughout her day. This helped her self-regulate so she could demonstrate her knowledge at school, complete her homework, make friends, and be a more integrated part of her family. With the many children and adults that followed, success was observed using these simple terms to explain to children and adults the basic SI concepts as the foundation for self-regulation. Williams and Shellenberger refined their approach until the program “How Does Your Engine Run?®” was born and subsequently renamed “The Alert Program®.”

Rationale

To attend, concentrate, and perform tasks in a manner suitable to the situation, one must be in an optimal state of arousal for the particular task (Mercer & Snell, 1977). When difficulties in self-regulation occur, individuals have trouble changing their levels of alertness, which in turn compromises their ability to engage competently in their chosen tasks (Williams & Shellenberger, 1996). Ayres (1979) suggested that a variety of sensory inputs is necessary to keep the nervous system organized and regulated, thereby supporting engagement in meaningful occupational roles. The Alert Program® works to expand individuals’ awareness, repertoire, and use of these sensory inputs to improve their ability to self-regulate.

Research, particularly from the fields of education and psychology, is beginning to recognize multiple levels of self-regulation as being critical for laying the foundation for higher metacognitive functions (Baumeister & Vohs, 2011). During the past decade, the field of education has grown to recognize that student success in school is largely dependent upon how well students self-regulate (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013). A growing body of literature has examined the various types of self-regulation and the related neurobiological foundations for each. As the brain matures, more complex levels of self-regulation emerge, with neurobiological and functional interrelationships existing among the multiple levels of regulation (Shanker, 2012). **Sensorimotor self-regulation,** which Shanker (2012) refers to as biological self-regulation, is the most basic, foundational level and the focus of the Alert Program®.

Neurobiological literature has considerable evidence to support the notion that sensorimotor engagement enhances the development of underlying neural substrates and thus supports the ability to develop higher cognitive function (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2012). Sensorimotor self-regulation occurs at lower levels of the nervous system and supports the emergence of higher cognitive functioning, including regulation on emotional and social levels. In turn, higher cognitive functioning supports new learning that integrates lower sensorimotor functioning for more sophisticated processing of information. The Alert Program® capitalizes on higher cognitive functioning, using the cortex for thinking about self-regulation to help individuals recognize problems with lower level functioning (i.e., a "top-down approach"). They learn to select from and implement a range of strategies to change sensorimotor regulation (i.e., a "bottom-up" approach). In turn, improved sensorimotor regulation contributes to improved emotional, social, and behavioral regulation. By using sensorimotor strategies from the mouth, move, touch, look, and listen categories, the Alert Program® supports both "bottom-up" and "top-down" sensory-motor-cognitive developmental interactions and integrations.

Program Description

The Alert Program® is a framework that takes complex sensory processing information related to modulation and self-regulation and makes it accessible for the layperson. People who struggle with self-regulation frequently have difficulty transitioning between activities, coping with changes in routines, and generally adapting to the challenges of life. The Alert Program® was developed so that individuals can learn to be independent in self-regulation and team members can learn to support those individuals who cannot be independent in self-regulation. It is a low-budget, practical approach that supports the development of a sensory diet, a term coined by Patricia Wilbarger (1984).

The simple vocabulary and step-by-step process inherent in the Alert Program® promote learning about and enhancing one's own ability to self-regulate. Knowledge of self-regulation and a repertoire of sensorimotor strategies enhance one's abilities to learn, interact with others, and work or play within varied environments, in addition to building self-esteem, self-confidence, and self-monitoring skills.

Designed to supplement and strengthen established intervention programs, individuals wishing to use the Alert Program® are advised to determine the underlying causes of self-regulation difficulties through a comprehensive assessment. Most individuals with self-regulation difficulties will need occupational therapy with sensory integrative emphasis, in addition to using the Alert Program®.

There are *process* and *structural* elements that are critical for optimal success in implementing the Alert Program®. The *process* for implementation requires several elements or strategies, including an "inside-out" approach to learning, collaborative "detective work," critical reasoning and creative problem-solving, modeling of one's own levels of alertness and strategies, a jargon-free vocabulary, and supportive coaching through the developmental stages. The *structural* elements include qualified leadership, evidence of support team collaboration, adherence to core stages of learning, and appropriate space and equipment.

Anyone can be a leader of the Alert Program® (parent, teacher, family member, mental health provider, community support personnel, etc.); however, to expertly guide implementation, it is critical that an occupational therapist (or other related professional, knowledgeable and skilled in the theory of SI and the Alert Program®) be on the team in the role as leader or consultant to the leader. Adults who support a child's learning process need to be actively engaged in the learning process. These individuals act as a "support team." The make-up of the team varies depending upon the age and occupational contexts of the individual. The occupational therapist provides team members with information and experiences to help understand the key concepts of the program.

All team members need to be "detectives" in collaboration with the occupational therapist. Detective work encompasses observing states of alertness (see Fig. 18-2), identifying potential sensory strategies, and then applying sensory strategies while observing and asking, "Is it working?" Team members learn to interpret problematic behaviors from a sensorimotor perspective and teach children and adults how to help "set up the nervous system for success" using positive feedback and coaching.

The Alert Program® involves a developmental process for learning based on the idea that a greater understanding of "self" leads to greater understanding of others and, ultimately, to greater problem-solving—an inside-out approach. One of the methods to bring more awareness of "self" to team members is to ask them to complete the Sensory-Motor Preference Checklist (Williams & Shellenberger, 1992). This self-learning process is congruent with the three core stages that guide

FIGURE 18-2 The Alert Program® helps children and adults to monitor how alert they feel (on charts similar to the above or on speedometers).

learning about self-regulation through the Alert Program®:

1. Identifying one's own "engine speed" or alert levels
2. Experimenting with methods to change alert levels
3. Regulating one's own alert level: independent self-regulation in varied situations and contexts

Invariably, adults find that they use socially acceptable strategies as well as strategies that may be labeled "idiosyncratic." However, the same self-regulation strategies in children are often inaccurately labeled "inappropriate" or "problematic." Consistent with the inside-out approach, team members ultimately learn about their own nervous system needs, sensory-motor preferences, and patterns of self-regulatory strategies in an effort to better support adults and children.

Relationship to Sensory Integration and Occupation

Occupational therapists have long recognized the multiple factors that contribute to successful participation in occupation. The dynamic interactions among the individual, environment, and chosen occupation form a complex transactional relationship. The ability to self-regulate *affects,* and is *affected by,* the individual's performance skills, patterns, activity demands, and by contextual and environmental factors (American Occupational Therapy Association [AOTA], 2014). The Alert Program® influences individuals' intrinsic sensory function by assisting them in understanding how to become efficient and effective in changing arousal in response to the occupational context, thereby establishing or enhancing skill. To support this enhanced understanding and skill, the program also promotes finding ways to modify the environment or activity demands. The resultant outcome is enhancement of health and participation in life.

SI theory helps the practitioner understand the relationship between behaviors and ability to process sensory information. The Alert Program® was drawn directly from SI theory; it is a unique adaptation of the theory specifically addressing self-regulation. To assist individuals with self-regulatory and attention deficits, the Alert Program® applies basic principles of SI theory related to arousal states. Intervention strategies are embedded in day-to-day occupational tasks and routines. A child or adult is expertly guided to identify sensorimotor preferences, determining what fosters self-regulation skill development and enhancing occupational performance and participation in life.

Expected Benefits

The Alert Program® benefits the person who is learning to be independent in self-regulation. Additionally, those individuals who have yet to achieve or may not achieve independent self-regulation (such as infants or young children, those who are nonverbal with autism, those with developmental disabilities or cognitive challenges, those with psychiatric conditions, adults who have experienced trauma, or elders with dementia) may benefit through continual and individualized team member support.

The program is designed to (1) teach how to recognize states of alertness as they relate to attention, learning, and behavior; and (2) help recognize and expand the number of self-regulation strategies used in a variety of tasks and settings. Increased awareness of one's own self-regulatory needs and strategies typically results in the enhanced ability to focus, attend, and concentrate, resulting in more successful participation in everyday life. Individuals feel more efficient and effective in relationships and performance in daily occupations, leading to a more satisfying sense of well-being.

The goal of the Alert Program® is not to teach children or adults how to get "engines to run just right" and remain there throughout the day, but rather to learn how to *change* levels of alertness to meet situational demands. For example, parents and caregivers can support infants and young children (who are not developmentally able to self-regulate independently) by learning how to help the child's nervous system change from a disorganized, agitated state to one that is more organized and focused. A preschooler may need a parent's assistance to know how to self-regulate to change from a high state to a low state of alertness for sleep. A school-aged student can learn what to do before homework time to attain an optimal state of alertness for attending and concentrating. A college student needs to know how to self-regulate to stay alert for studying and maintain an optimal state while taking the examination to demonstrate her knowledge. An adult with autism who is nonverbal may need guidance from a knowledgeable support team to help him stay alert at work in a community setting. Adults learn what they can do after lunch when their nervous systems are in a low alert state yet they need to be productive at work. Elders with dementia can be skillfully directed to use self-regulation strategies that decrease anxiety and agitation to help them participate in meaningful activities. The program has been successful with both children and adults (who are developing typically or atypically, verbal or nonverbal), suggesting that all individuals can benefit from greater awareness of self-regulation.

Research and literature related to self-regulation and the Alert Program® are growing and provide evidence related to the benefits of the program's use. Barnes and colleagues (2008) found the Alert Program® to be effective in helping children with emotional disturbances to change tasks, organize themselves, cope with sensory challenges, and focus on tasks in the classroom. Bertrand (2009), Wells and colleagues (2012), and Nash and colleagues (2015) found significant improvements in emotional and executive functioning of individuals with fetal alcohol spectrum disorders (FASD). Currently, there are large, ongoing government-funded studies in both Australia and Canada focusing on self-regulation issues with individuals with FASD and the use of the Alert Program® as an intervention. Mac Cobb and colleagues (Mac Cobb, Fitzgerald, & Lanigan-O'Keefe, 2014; Mac Cobb, Fitzgerald, Lanigan-O'Keefe, Irwin, & Mellerick, 2014), studying the use of the Alert Program® with socially disadvantaged students in Ireland, found that students demonstrated enhanced self-management skills resulting in greater self-efficacy in students with a history of low achievement in school. A whole school approach is being considered.

Unpublished graduate studies also provide important data for review. When applying the program in a self-contained language-learning disability classroom, Chiodo (2010) found an increase in attention to task and a decrease in the need for redirection during activities. The Alert Program® was found to be the main contributing factor to improving communication and interaction skills of adults with severe and persistent mental illness (Clark, Pritchett, & Vandiver, 2011).

Less rigorous research studies published in professional magazines also provide important evidence. Through a case-study format, Feldman (2012) found the Alert Program® to be successful in helping a pre-adolescent with an anxiety disorder to gain critical self-knowledge and skills related to self-regulation. Schoonover (2002) provided another case example demonstrating improved social skills of children in a school-based program. Additional citations to support evidence-based practice and extensive review of literature related to the program can be found in the document titled "Alert Program® Literature and Research," at AlertProgram.com.

Target Populations

Individuals of all ages need the ability to self-regulate for successful occupational engagement in the world. Although the Alert Program® was originally developed for children with learning disabilities, 8 to 12 years of age, it has been adapted successfully for use with individuals across the age span. The program is often used with individuals (1:1), but it is also effective and has been used with groups and on a system-wide basis, such as an entire school district, corrections facility, or mental health facility.

The authors have implemented adaptations of the Alert Program® concepts for all ages, from infants to elders, for a wide variety of populations, including individuals with autism, attention deficit disorder, FASD, developmental disabilities, medical fragility, physical impairments, social skill challenges, and mental health issues. They have provided Alert Program® consultation in schools (public and charter at all levels and around the world), homes (home schools and family consultations), therapy clinics, college classrooms, skilled nursing facilities, chronic pain clinics, aquatic therapy programs, and camp settings. They have assisted preschool, Head Start, elementary, middle, high school, and university staff and administrators; foster care providers; adoptive families; and camp counselors to successfully adapt the Alert Program® to the needs of children and adults.

Training Recommended or Required

Although formal training is not required, it is recommended that anyone who facilitates the Alert Program® with children or adults complete a 2-day program, which is available live or online. This is particularly critical for those researchers and others implementing the program system-wide or to large groups of individuals.

The Alert Program® publications and materials were developed to guide the implementation of the program. The theoretical foundations (grounded in SI concepts) and conceptual framework for the Alert Program® are documented in four books and in an online course. Since the early 1990s, a variety of publications and free resources have been developed, including self-regulation activities, songs, and games, as well as workshops and distance learning opportunities.

CASE STUDY: ALERT PROGRAM® IN A PUBLIC SCHOOL SYSTEM

The following case example provides a brief description and selected results of a system-wide implementation of the Alert Program® within a public school district including more than 30 elementary schools. It demonstrates that occupational therapists can obtain stronger and more successful outcomes when they include support team members. Implementation on a larger scale provides evidence of the Alert Program® success and school-wide influence in helping school-aged students develop skills in self-regulation and subsequent learning.

Throughout much of the past decade, this school district documented steady increases in general education kindergarten enrollments of children with poorly developed social-emotional readiness for learning. Teachers requested tools to help students who were developmentally not ready to learn. Occupational therapy referrals increased beyond available resources, prompting the therapists to examine the issues more carefully and consider solutions for such pervasive performance skill concerns. In analyzing the trend, it became evident that many of these children were lacking the ability to self-regulate, a core competency that is foundational to social-emotional development and ultimately to academic success. The Alert Program® was identified as a viable and practical framework for addressing such a large-scale problem, and a strategic plan for gaining support of its use system-wide by administrative decision-makers was initiated.

First, occupational therapists provided opportunities to allow administrators to observe therapists collaborating with teachers in the classroom using the Alert Program®, learn about their own personal self-regulation needs and strategies, foster an understanding of the underlying theory behind the approach, and gain a clear understanding of potential short-term and long-term outcomes. Ultimately, the administrative leaders identified sensorimotor self-regulation as a core competency and provided necessary resources to support a district-wide program focusing on the development of self-regulation as a competency initially for all K–2 children (and later expanded to older students).

Occupational therapists designed a comprehensive plan for implementing the Alert Program® and the therapists, acting as consultants, guided its implementation. Teachers were trained in the core concepts and principles of the Alert Program®. Multiple resources, activities, and strategies for implementing the program were put into place in an effort to support teachers in integrating the concepts into day-to-day teaching routines. The teachers became the "leaders," and the therapists were highly involved consultants. All students in general education classes participated, and any students whose special needs were not met by the consultation model obtained direct occupational therapy services, as needed.

"Tracking Success" (McEwen, 2009), a strategy to assist with evaluating the efficiency and effectiveness of the district-wide program, was used to identify gains in three distinct aspects of the program: (1) student learning, (2) professional practice and learning, and (3) school culture and climate. The results are too extensive for complete discussion here; however, select outcomes pertaining to teacher perceptions, confidence, and application are described next.

In an annual teacher survey, 74% of the participating teachers responded to questions related to their perceptions and use of the Alert Program®. Use of sensorimotor self-regulation strategies in the classroom was reported by 97% of the teachers who had received the Alert Program® 2-day training. Of those teachers, 82% found the approach to be highly valuable and compatible with their teaching practices. A majority of these teachers (78%) reported applying the approach to the entire class. Most (93%) of the teachers reported observing and understanding student behavior from a different perspective, with 84% having gained knowledge about how to change the structure and routine of their classroom to support learning. More than one-half (57%) observed improved student levels of alertness and attention in the classroom.

These and other more extensive data reflect the value and benefit of the Alert Program® when implemented system-wide. Not only did individual children gain self-regulation skills, but teachers found an effective tool and necessary support for classroom implementation in their efforts to support the development of self-regulation skills with their students.

Section 3: Aquatic Therapy

Gudrun Gjesing, Occupational Therapist, Specialist in Children's Health & Swimming, Coach and Lecturer

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
Aquatic therapy	• Integrated • Active	• Responsive	• Nontraditional

Background

Throughout history, water has been associated with life and health. People throughout time have flocked to places with healing springs. In ancient times Romans, Greeks, and Incas, among others, built baths both for cleaning their bodies and purifying their souls and minds. Today we relax in bathtubs, hot tubs, and SPAs. (SPA is an acronym for *sane per aqua,* which means "health through water.")

One can think of aquatic therapy as a means of radically changing the environment such that the new environment provides many new possibilities for stimulation. In water, you create a situation in which children are submerged in an ever-changing environment where the force of gravity is not dominant as it is on land. Water acts on the body in accord with the laws of physics: buoyancy, pressure, turbulence, and current. Therapists who work with children in the water need to learn both the theory and practical application of these laws, including hydromechanics. They also must learn appropriate skill acquisition in the water; how to analyze activities, toys, and equipment used in water; and how to handle children in ways that turn water activities into therapy.

Rationale

All of us began life in water. Before birth, we grow and play in "aqua vitae" (the water of life) in our mother's womb. In this element, the embryo moves naturally, and its sensory systems are stimulated by its own movements and its mother's movements. Because of the buoyancy of the water, the embryo moves freely in three dimensions without the need of a firm base. That freedom of movement in water will always be present. Nobody is born with fear of water; quite the opposite is true. Unfortunately, some people *learn* to fear water, often because of an anxiety-producing experience and sometimes the result of poor instruction. Those people must re-master moving in water if swimming and other water activities are to be fun.

Water stimulates the *tactile system* over the entire surface of the body, and the input changes constantly as both the water and the child move and different body parts break the surface intermittently. Because of constantly changing stimulation, the tactile receptors cannot habituate. Hydrostatic pressure yields deep pressure on the whole body and, when lying supine in the water, individuals feel grounded through the tactile sensations received along the whole back. They seldom experience tactile defensiveness when submerged. Children also receive tactile input in the changing room and shower from the running water in the shower, washing the whole body with soap, drying with a towel, and applying body lotion.

The *vestibular system* similarly receives enhanced input throughout aquatic therapy sessions. Water invites moving in both the vertical and horizontal planes and in all planes in between, offering much greater variety of position and movement than is possible on land. Diving, swimming, and floating activities in this ever-changing environment give rise to constant starts and stops, and changes of direction and position. Balance is constantly challenged by currents and water turbulence, and the body rotates in water as soon as it is not symmetrical in shape. Therefore, children must pay a lot of attention to balance control. They learn to use head position to control the whole body, to initiate desired movements, or to prevent undesired movements. All of these postural adjustments give rise to vestibular input. Because most of the body is submerged, children cannot see the body well; thus, they cannot compensate for poor processing of vestibular information through vision.

The changing room and shower also yield substantial vestibular input because of changes in head position and challenges to balance. Some examples include tilting the head backward with eyes closed to wash hair, bending the head forward to wash feet, bending down to remove or put on socks and shoes, balancing on one leg when putting on trousers, putting on pullover garments that occlude vision, and navigating the changing base of support that comes with a wet floor.

Aquatic therapy also yields enhanced *proprioception*. Without a firm support surface, one can move freely in water, and the sensation of movement is experienced strongly because of resistance felt from the water. However, because of buoyancy, one gets less proprioceptive input from the legs and trunk when standing upright in shoulder-deep water than when standing in the same position on land. The resulting decrease in pressure to joints and resistance to muscles means there is a need to pay greater attention to body positions when stationary in water. Although proprioception may be decreased when a child is stationary, water is nearly always moving and, to maintain a position, children must counteract the force of the water, which in turn generates proprioceptive input.

In addition to the tactile, vestibular, and proprioceptive systems, *other sensory systems* also receive different input in water compared with on land. Some can be unpleasant, causing children to not want to get their head under, or near the surface of, the water. Water in the ears and eyes can cause feelings of discomfort and insecurity, as well as affect hearing and vision. Water in the mouth and nose can taste and smell unpleasant. Nonetheless, children usually learn that the fun of being in water compensates for any discomfort.

Program Description

The section author has conducted aquatic therapy groups weekly in a local public swimming pool for more than 30 years with children ranging from 8 weeks to 12 years of age. (Note: Although this author works primarily with children, the description also applies to adults.) Babies and children who are not yet able to be free in water are accompanied *in* the water by an aide. The aide may be a parent, a grandparent, other relative, or a caregiver—someone the child knows well, and the same aide each time.

Before going into the water, the aide must be trained in the theory and practice of water activities, including appropriate support of a child in the water. Aides give children both physical and psychological support. They use their hands to facilitate balance reactions in different positions during different tasks, so it is essential that they know the appropriate techniques for handling a person in the water. This may be quite different from the appropriate handling of the same person on land.

To avoid disturbing the child's own balance reactions, the aide provides support at the body's center of balance, about waist level. Foam and inflatable floatation aids are used as infrequently as possible because they are static and may disturb the child's learning of balance reactions. In contrast, hands are sensitive and dynamic, and they can adapt to the just right support and challenge, according to the child's position in water, the tasks, and the child's actual ability and needs. This is *science* and *art* in combination.

Group size is optimal with six to eight children. Groups are formed according to the individuals' *abilities in the water* rather than diagnosis, age, or challenges on land. The most appropriate water temperature and depth also are important considerations in forming groups. *Water temperature* is approximately 84°F (or 28°C), although it should be some degrees warmer for young babies, as they have not yet learned to regulate body temperature properly. If water temperature is higher than skin temperature (approximately 92°F or 33°C), the water will heat the body, resulting in decreased activity. When water temperature is lower than skin temperature, it promotes being active and moving around, in order to keep the body warm.

The *depth of the water* varies from 3 to 12 feet (1 to 4 meters). When you are standing upright with the water just below waist level, balance reactions will be similar to those on land because gravity is the dominant force. When the body is submerged to shoulder level, buoyancy dominates, and balance reactions are controlled by the head and shoulders. The phrase "No shoulders out of the water," referring to both children and aides, is an attempt to draw on the special attributes of the water as much as possible.

As with intervention on land, the instructor (therapist) often motivates children through playful interactions (Fig. 18-3). We use objects that are easily seen in water to promote understanding of the tasks and sometimes just for fun. We use both objects that float and those that sink (e.g., small and big balls, balloons, clothes-pegs, small rings, hula-hoops, water pistols, umbrellas, and buckets). With children, we use a lot of well-known action songs and rhymes. The instructor and the aides are often included in the activities, which provide useful feedback, both internal (i.e., knowledge of the body) and external (i.e., knowledge of the results of their actions).

Games need groups, and groups need games! The instructor designs group games and learning situations with every child in mind. For example, children anticipate movement patterns associated with songs, rhymes, and objects. In addition to planning movements, the activities also engage attention and prompt social interactions. Later, the same movement patterns are incorporated into purposeful "water skills" (e.g., automatic inhaling only when nose and mouth are out of the water; body stability; rotational control; mobility; and, for some, swimming strokes).

Some activities have goals that are specific to particular individuals. Instructors can create "stations" at the edge of the pool, using pool markers. Each station contains objects and instruction with written clues, photos, or drawings for children to decide how to solve the challenge, using imagination. The instructor gives individualized suggestions to children to make activities simpler, ensuring success, or more challenging, increasing engagement. One important desired outcome

FIGURE 18-3 Using a water pistol in the swimming pool increases the fun. *Photo courtesy of Gudrun Gjesing.*

is that all children are open to new goals. One example of a station would be placement of clothes pins and textured dish rags at the edge of the pool, with a weighted string hanging off the edge and traveling down into the water. One task goal would be to attach the dish rags to the string with the clothes pins as far down to the bottom of the pool as they can. The tasks could be modified so that one child may put the dish rags on the string without submerging, whereas another child would do the task having to fully submerge. The task goal could also be modified using the same materials; for example, a goal could be for a child to pick the clothes pins off the bottom of the pool floor with their toes or hand the clothes pins to another child who then attaches them to the string.

Each water session should include both activities tailored by the instructor and time for engagement in self-selected, self-initiated, and self-organized activities. The latter are more likely to be meaningful to children while, at the same time, promoting adaptive responses.

Relationship to Sensory Integration and Occupation

Aquatic therapy provides opportunities to actively take in enhanced tactile, vestibular, and proprioceptive sensations, and it demands adaptive responses. Thus, aquatic therapy promotes SI, and, although it looks very different from traditional sensory integrative therapy and is delivered in a markedly different environment, the overlap of principles is apparent. Carefully designed aquatic therapy programs promote praxis, sensory modulation, and successful engagement in occupation—in water and on land.

With regard to occupation, aquatic therapy programs may lead to children becoming members of swimming clubs, going with family or friends to public swimming pools, and going on holidays near bodies of water. Such recreation is fun for the whole family and capitalizes on children's abilities rather than emphasizing their disabilities. In addition, aquatic therapy programs facilitate numerous occupation-based gains: planning (e.g., packing the things needed at the pool), undressing and dressing, showering, washing hair, toileting, and perhaps even using public transportation. Therapy is apparent in the changing room as much as the pool. Aides are taught not to help children with tasks they can do themselves, to assist with tasks the children are practicing, and to do only what a child is not yet able to do. Children readily understand the need for performing these skills in the context for which they are required.

Expected Benefits

Water can be a powerful and highly motivating therapeutic medium. Several physical benefits can be realized, including improved respiration and breath control, stability and control of movement, rhythmicity, coordination, and fitness. Psychosocial and learning benefits also are described, including improved skills for working in groups (e.g., paying attention to, waiting for, and supporting others); learning by imitation; self-assessment; self-esteem; comfort with being close to, and dependent on, others; and developing new friendships.

When one considers all these potential gains together, the possibility for improved quality of life does not seem a big stretch. Many skilled therapists with years of practical experience describe the benefits they have seen repeatedly. They believe strongly in the enduring effects of aquatic therapy on everyday functioning. And although there is research supporting the benefits of aquatic therapy for children with autism (Vonder Hulls, Walker, & Powell, 2006; Yilmaz, Yanardag, Birkan, & Bumin, 2004), cerebral palsy and other neuromotor conditions (Dellaratta, 2002; Getz, Hutzler, & Vermeer, 2006; Maynard, 2004; Sterba, Safar-Riessen, & DeForest, 2004), juvenile rheumatoid arthritis (Epps et al., 2005), and other conditions, research concerning the effects of aquatic therapy for children with SI dysfunction is not yet available.

Target Populations

People of all ages and with all types of challenges may benefit from intervention in water. The goals that the therapist sets together with children or caregivers and the way the therapist designs and implements programs will vary according to each child's specific needs. This section focused on aquatic therapy for individuals with sensory integrative dysfunction, with whom it can be used to address challenges with maintaining optimal arousal, alertness, self-regulation, and modulation, as well as with praxis and gravitational insecurity.

Some children with sensory integrative dysfunction as a primary or secondary diagnosis also have other difficulties that may respond to aquatic therapy, such as neuromotor disabilities (e.g., cerebral palsy), emotional disorders (e.g., because of sexual abuse, neglect, or other trauma), behavior disorders, learning deficits, speech deficits, and visual and hearing impairments. Aquatic therapy also provides a natural context for working with babies and their parents or caregivers to promote attachment, playfulness, resilience, self-confidence, body awareness, respiration, head control, and control of movement patterns.

Training Recommended or Required

Learning to provide aquatic therapy involves experiential learning. An instructor must be trained in three areas: hydromechanics, water safety instruction, and the *art* of therapy (i.e., making therapy motivating and matching it to the needs of children; see Chapter 12, The Art of Therapy). Instruction in hydromechanics as well as the technical expertise of teaching water skills (i.e., what we do in water, why, and how we do it) may be learned through study of the Halliwick Concept (Halliwick Association of Swimming Therapy National Education Committee, 2010). Instructors must be trained to do continuous qualitative assessment of children's abilities in water, to adjust goals and plans appropriately as abilities change. They must also continually assess activities and playthings (i.e., how to make activities simpler or more challenging) so they match each child's needs. This principle of "grading" helps to make activities tempting and obviate the need to resort to manipulation or demands when instructing. Aquatic instructors are not always therapists; in that case, a therapist should serve as a consultant to the program, assisting with assessment, tailoring goals, and helping to analyze playthings and activities. [Note: In the United States, swimming instructors must be certified in water safety instruction. This certification is available from the American Red Cross.]

CASE STUDY: "THE ALARM CLOCK"

"Come on, now we are going to do the Alarm Clock!" the instructor says. All the children and their aides immediately know exactly what is going to happen, and they begin to prepare. The children form a circle in an upright position facing the instructor. Their aides support them from behind according to each child's needs, so all get the *just right* support and challenge. The instructor then says: "Now you are going to sleep, all of you, with your eyes closed!" The children move to a supine position by bending their head backwards into the water and letting their legs float upwards (Fig. 18-4). The children receive vestibular stimulation by changing their head position without using vision and tactile stimulation from movement of water and from the hands of the aides. Goals of this part of the activity could include participation in a social activity, maintaining appropriate levels of alertness and attention, and preparing for and moving from one stable position into another.

Then the instructor moves around the circle, touching each child's feet when saying his or her name. "Now I can see you are all fast asleep!" The children take in tactile, proprioceptive, and vestibular sensation. New goals of this part of the activity could include holding a position in an ever-changing environment and remaining calm and relaxed when lying supine with eyes closed.

"Ding-a-ling-a-ling!" the instructor yells until all children have moved as quickly as possible from supine into a vertical position again by flexing the neck and hips and stretching the arms forward. As they move into the vertical position, the mouth may go under water, and they must either close the mouth or blow bubbles. The children take in tactile, proprioceptive, and vestibular sensation. Goals of this part of the activity could include changing head position quickly, changing body position without using vision as the body is submerged in the water, and having controlled mouth closure or making bubbles.

The instructor continues making the alarm sound until all children have placed one hand

FIGURE 18-4 "Now you are going to sleep, all of you." *Photo courtesy of Gudrun Gjesing.*

FIGURE 18-5 All of the children place one hand on the "alarm button." *Photo courtesy of Gudrun Gjesing.*

on "the alarm button" (the instructor's head) and they start pressing her down into the water (Fig. 18-5). Again, the children take in tactile, proprioceptive, and vestibular sensation. Goals of this part of the activity include the ability to bend the head forward while stretching the arms and keeping the trunk stable while exerting resistance and working together. The instructor stays submerged as long as possible. As she emerges, all the children yell: "Let's do it again!" (Fig. 18-6).

Learning really goes swimmingly. . . .

FIGURE 18-6 "Let's do it again!" *Photo courtesy of Gudrun Gjesing.*

Section 4: Interactive Metronome®

Beth Osten, MS, OTR/L

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
Interactive Metronome®	• Single system • Passive application	• Prescribed	• Traditional

Background

Interactive Metronome® (IM) is an evidence-based computer technology that can be a useful adjunct to sensory integrative intervention. This program is designed to improve timing and rhythmicity, which are necessary to perform several functional skills and play tasks and that are commonly problematic for children with sensory integrative dysfunction, especially dyspraxia. The original metronome that has been used for centuries to help musicians improve their timing and rhythmicity inspired the IM program. The developer, James Cassily, worked for many years as a sound engineer in the recording industry, and in 1992 he initially devised the IM for use by musicians. This newer IM technology improves on the original metronome by adding an auditory feedback component that is linked to the timing of movement patterns used to activate a switch.

Early in the development of the IM, a physician suggested that it might be useful for children with severe movement problems. As clinical trials progressed, observations indicated improvements not only in the timing of movements but also an impact on a broader range of functions. The program drew the attention of Dr. Stanley Greenspan, who, in 1997, became the director of IM research. In 1999, the program was made available to trained health-care professionals, and, in 2001, a version was released for use in mainstream settings, including academic settings and athletic training venues.

Importantly, structured movement activities such as the standard IM program are not considered sensory integrative therapy, as described by Ayres. Rather, IM can be a useful adjunct to an SI therapy plan.

Rationale

Rhythmicity, or timing, is inherent to the human organism and is the foundation of many human functions. Neural rhythmicity is reflected in brain waves that can be measured by sophisticated brain scanning and EEG monitoring technology to tell us how complex neural networks fire in synchrony to produce coordinated perceptual and behavioral responses (Bear, Conners, & Paradiso, 2015).

Within the human brain, synchronous rhythmic activity appears to be coordinated by two types of neural processes. The first is a pacemaker process, whereby a small group of cells acts as the timekeeper for other functions. Within the thalamus, internal cellular activity occurs, in which single cells fire rhythmically without external influence and in turn synchronize with other thalamic cells. Connections between excitatory and inhibitory thalamic cells generate coordinated rhythmic activity, which is then sent to the cortex to act as a pacemaker for a larger group of cortical cells (Bear et al., 2015).

The second source of rhythmic activity is generated by the collective behavior of cortical circuits, or brain networks, which coordinate into synchronous patterns of activity that can be either localized or spread to larger areas of the cortex. This synchronized rhythmic activity may serve to increase the speed and efficiency of information processing during complex functional activities and aspects of executive functioning (Bear et al., 2015). Although there are several theories to explain various classes of neural timing, teasing apart the neural mechanisms has proven difficult (Lewis & Walsh, 2005). Many areas of the brain, which are interconnected in complex neural networks, appear to be involved. The cerebellum, basal ganglia, anterior cingulate cortex, dorsolateral prefrontal cortex, right parietal area, motor cortex, and frontal-striatal loop have all been identified as playing a role in timing (Buhusi & Meck, 2005; Lewis & Miall, 2006).

McGrew (2013) proposed a three-tiered model based on current neuroscience research to explain the positive effects seen in a broad range of functional areas following IM training. He proposed that IM training impacts precise timing mechanisms that occur at millisecond intervals and that, although there are domain-specific effects (such as the improvement of the movements being trained), there are also domain-general effects. Domain-general effects refer to the broad range of functional improvements noted in areas that have not been the specific focus of the training.

The outcome of this rhythmic brain activity can be observed through a wide variety of human behaviors that occur within an individual, from sleep-wake cycles and respiration to dance performance and athletic ability. Timing and rhythmicity are key factors in coordination, motor planning, and motor execution. Individuals with motor deficits may display any number of timing-related issues, including difficulty timing the initiation of movement (which may occur too soon or too late for successful execution of a task) or the pace of movement (which may be either too fast or too slow). Inability to time the termination of movement, as well as poor anticipatory timing, can also impact success. Aspects of movement, which may be additionally impacted by movement disorders, can include coordination of movements and sustaining rhythmic patterns of movement, as well as timing and coordinating the use of force (Cermak & Larkin, 2002; Shumway-Cook & Woollacott, 2007).

Rhythmic activity is also highly interpersonal. Motor timing and rhythmicity first appear functionally in early infancy within the contexts of feeding and interactive synchrony with the caregiver and are influenced by the maturation of timing mechanisms that organize before birth at around 30 to 34 weeks gestational age (Doussard-Roosevelt, McClenny, & Porges, 2001; Feldman, 2006; Mirmiran & Lunshof, 1996). In studies of premature infants, Feldman

(2006, 2007) found that the organization of physiological oscillators appears to lay the foundation for an infant's ability to participate in rhythmic parent-infant interactions. Parent-infant interactions have measurable, developmentally determined, temporal patterns that predict later developmental capacities for attention and regulation; and affect attunement, interactive reciprocity, and early preverbal and verbal communication (Beebe et al., 2010; Papoušek, 2008; Porges, 2009; Schore, 1996, 1997; Stern, 1984; Tronick, 2007). Even complex, high-level functions, such as symbolic play (Feldman & Greenbaum, 1997); self-regulation at 2, 4, and 6 years of age (Feldman, Greenbaum, & Yirmiya, 1999); and the capacity for empathy in adolescence (Feldman, 2005) have been linked to the timing and rhythmicity of early parent-infant interactions.

Because of the pervasive influences of timing and rhythmicity on human functioning, it is understandable that the development of effective intervention methodologies is desirable. From its initial inception, IM has offered promise as an intervention for children with functional deficits that are founded in timing errors. Clinical reports suggest a broad spectrum of positive effects, but controlled, peer-reviewed research on IM effectiveness remains sparse. In addition, research has been conducted on a range of populations varying in age and the nature of physical and developmental status. Selected published studies are reviewed in the Expected Benefits section of this chapter.

Program Description

IM is a computer-based software program that can be used in a wide variety of ways on either Macs or PCs. Different versions of the IM software are available for either desktop or laptop computers; these computers are purchased separately. The IM program also comes with headphones and triggers. Two contact triggers, or switches, are standard: a hand trigger, which comes in two sizes and connects by Velcro to a glove; and a foot trigger (approximately 6 by 12 inch), which is a thin pad that can be placed on the floor and is activated by the child's foot. Both the hand and foot triggers are available in wireless models. In addition to these standard triggers, the "In Motion" heel strike-activated sensor is available for use in assessing and training gait. Other commercial switches can be used instead to tailor the program to the needs of each child. Any two switches can be used at one time. Speakers can be used instead of headphones for individuals who might not be able to tolerate headphones, but the auditory input will be less specifically localized.

When in use, the IM software generates a steady beat through the headphones, and the user is asked to respond by producing continuous rhythmic movements of the hands or feet in response to the metronome beat. The triggers register the contact, and the software analyzes the timing relative to the beat. Guide sounds, delivered via the headphones to one or both sides, indicate whether the movement is early, late, or on target to the auditory stimuli. The response time is measured in milliseconds, and scores are given for accuracy, variability, and number of consecutive on-target beats. An in-a-row threshold can be set to increase the difficulty for consistency of performance. Visual feedback is provided on the computer screen to allow users to adjust rhythm and timing in order to synchronize movements to the metronome beat. The visual stimuli include animated images with game-like features that give feedback on accuracy and make the program more appealing, especially to children and adolescents.

The standard protocol consists of 13 different movement patterns that involve the upper and lower extremities and are performed bilaterally, ipsilaterally, contralaterally, or reciprocally. Some of the movement patterns include clapping the hands together in midline, clapping one hand at a time against the side of the body, alternating toe tapping between each foot, and alternating toe tapping and hand tapping. The standard movements are described in the IM manual (Interactive Metronome®, 2007). The standard IM training program consists of 12 to 15 sessions with predetermined objectives and specific instructions for the session, including the duration of each exercise. The protocol involves training the timing and accuracy of the movement patterns and training the user to increase focus and attention on the coordination of the movements with the metronome beat. A certified trainer must administer the program.

Relationship to Sensory Integration and Occupation

IM is a structured, therapist-driven program that addresses attention, timing, rhythmicity, and motor coordination, which support efficient motor planning and sequencing that, in turn, contribute to functional skills and support occupational performance. The IM program is considered to be a sensory-based approach because the auditory and visual *feedback* provided by the program allow for the timing of movement patterns to be adjusted. It is further theorized that moving to the repetitive auditory beat trains anticipation of movement that is characteristic of *feedforward* actions. Anticipatory preparation is necessary to perform complex movement sequences in a timely and automatic manner.

IM technology can be used in ways other than the standard protocol to make IM fun and engaging. For example, IM technology can be incorporated into SI therapy activities to strengthen multisensory processing and sensory feedback. Variations of movement patterns, positioning, incorporation of other movement modalities, and adjustments in timing can be used to adjust difficulty and to accommodate to the needs of the user. Principles of motor learning theory also apply to the IM.

Upon completion of the standard program, users will have completed up to 35,000 repetitions. This accounts for the gains in timing and rhythmicity seen in the program activities but does not account for broader gains that do not reflect the direct practice of the timed movements within the protocol. These broader changes may reflect shifts in the internal organization of timed functions, which would be more in keeping with dynamic systems theory. IM has been described as a top-down approach, but the impact of the program appears to affect bottom-up processes.

Expected Benefits

Many benefits from IM training have been reported in children and adults with a broad spectrum of clinical conditions, including improvements in attention and focus; motor control, as seen in improved accuracy and timing of movements; improved coordination; and faster reaction times. Several authors (Bartscherer & Dole, 2005; Cosper, Lee, Peters, & Bishop, 2009; Shaffer et al., 2001) reported improvements in regulation of aggression and impulsivity. Cosper and colleagues (2009) noted trends toward improvement in balance, response speed, visual motor coordination, upper limb coordination, and upper limb speed and dexterity scores on the Bruininks-Oseretsky Test of Motor Proficiency. Johansson, Domellöf, and Rönnqvist (2012) noted significant improvements in the speed of movement, quality of movement, and efficiency of movement following IM training in two adolescents with cerebral palsy. Improved athletic performance in typical adults has also been reported (Libkuman, Otani, & Steger, 2002; Sommer & Rönnqvist, 2009).

Anecdotally, many therapists have noted improvements in children's balance, fluidity of handwriting, keyboarding, and visual pursuits. Many families and clinicians report positive changes in behavior and attention, decreases in anxiety, and improvements in organization and self-initiation. Interestingly, improvements have also been noted with regard to aspects of language processing, speech production, and reading (Sabado & Fuller, 2008; Taub & Lazarus, 2013; Tierney & Kraus, 2013).

With any clinical tool of this nature, differences in intervention outcomes can be expected in individuals with different clinical conditions and comorbidities. Because each child presents with his or her own unique profile and issues, each individual will respond somewhat differently to any type of intervention. What is statistically significant for a large group will not necessarily be true for each individual. For this reason, the use of IM training should be part of a comprehensive intervention plan based on thoughtful clinical reasoning.

Target Populations

IM is currently used with a wide population of individuals, including children and adults with learning disabilities, attention deficit disorder/attention deficit-hyperactivity disorder (ADD/ADHD), autism spectrum disorders (ASDs), and cerebral palsy. IM has been used with individuals with balance problems; motor coordination disorders; functional gross and fine motor deficits, including difficulties with handwriting and keyboarding; and more complex motor planning and sequencing difficulties (dyspraxia). IM is also used for executive functioning disorders, including issues with attention and focus, poor organizational skills, memory deficits, and regulatory issues. Research has supported the use of IM with individuals with language deficits, including difficulties with listening comprehension, verbal expression, reading comprehension, and difficulties with the motor and sequencing aspects of language (Sabado & Fuller, 2008; Taub & Lazarus, 2013; Tierney & Kraus, 2013).

More recently, IM has been used in the treatment of individuals with traumatic brain injury, stroke, multiple sclerosis, and Parkinson disease. IM is gaining popularity among the typically developing population for athletic training, academic skills enhancement, and musical and dance training.

Generally, IM is recommended for use with individuals with a developmental level of 6 years or older, but clinicians are beginning to use adapted versions of IM with younger children and with more involved populations. As with any intervention, appropriateness is a clinical decision, and the varying degrees of severity will indicate appropriateness.

Training Recommended or Required

Certification and continuing education in the use of IM is available electronically through the IM website (http://www.interactivemetronome.com/). In-person training is also offered throughout the United States and internationally. A certificate for using the IM program can be obtained in one day via approved training courses. IM equipment is only available to trained administrators. A home version is available for use under the supervision of a trained therapist or administrator. The home version can be monitored and the program adjusted by the trainer via an Internet connection.

Case Examples

Two short case vignettes presented here provide a summary of the use of IM with children; different models of practice are used in each. For these two children, IM was combined with other interventions, as has been noted to be appropriate. A third, more descriptive case study is presented following the vignettes, which includes some greater detail on the IM intervention.

CASE STUDY ▪ LARS

Lars is an 11-year-old boy who lives in Europe. He has a diagnosis of high-functioning autism. He initially presented with significant sensory processing and motor involvement. He had very low muscle tone, poor postural control, and severe dyspraxia. He was hypersensitive to many types of sensory input, was extremely anxious, and became dysregulated easily. His family had done intensive bouts of therapy and sought consolation from a large SI and floortime therapy practice in the Chicago area. Occupational therapy service providers in their area were difficult to find, and the models of intervention used were not fully what the family wanted for their son. The family set up a small SI gym in their home. Lars made excellent gains in response to consultative therapy with follow-up at home by the parents. He was receiving speech therapy through his school, and the family eventually found a therapist to do SI work with Lars with input from the occupational therapy consultant from Chicago.

Following a short visit to Chicago, it was decided that Lars might benefit from adding IM to his SI therapy. The consultant suggested the IM Home program with oversight by the local therapist and monitoring via Internet by the consulting therapist. Lars did the standard protocol during about 4 months, making nice improvements on his timing. Functional gains in motor skills, fluidity of handwriting, and improved attention were noted by the family and Lars' school team. The greatest benefit, however, was in the area of regulation. Lars found the IM exercises very relaxing and, after completion of the protocol, he spontaneously requested time on the IM program. He made up his own "moves" and used some of the old ones. He would work on the program for 10 to 15 minutes when he came home from school. This lasted for more than a year until he gradually stopped using the program.

On follow-up, many of the initial gains in attention continued to improve, and changes in his vocal prosody were noted. As a high school freshman at a competitive private school, Lars has done well academically. He has a small circle of friends and is generally well liked. He continues to have difficulty with postural control, athletics, and handwriting, but he has become proficient at keyboarding. It is anticipated that he will be able to attend college.

CASE STUDY ■ GEORGE

George is a 9-year-old boy who lives with his family in a small rural Oklahoma town. The family originally lived in Chicago and, when developmental delays became apparent when George was a toddler, the family established connections with a team of therapists. George was never formally diagnosed but had features of autism. He made excellent progress in therapy, especially in his ability to be socially engaged and reciprocal. Although language was late to emerge, he eventually became verbal.

When George was 6, his family relocated because of his father's job, and access to services was more difficult. When George entered school, he was placed in a regular classroom with support. The family maintained connections in Chicago and periodically went to Chicago for intensive interventions lasting 1 to 3 weeks. When the family returned home, follow-up intervention suggestions were offered, and his local therapists followed through and consulted with his Chicago team.

When George was 9, he went to Chicago for a 3-week combined SI and IM therapy. He received IM in the morning and SI for an hour in the afternoon, as well as speech therapy for an hour every day. At the time, George continued to display quite low muscle tone, difficulty with postural control, poor body awareness, motor planning deficits, and significant difficulty with visual-spatial problem-solving. His language processing was still impaired, with a very slow response speed, difficulty with verbal formation, and halting prosody. Because of the time constraints of the 3-week intervention, a standard IM protocol was administered during 15 one-hour sessions. George started with scores that ranged from 160 milliseconds off the beat to up to 250 milliseconds off the beat for the more difficult IM movement patterns (40 to 60 ms is more typical of a child his age). Following the IM training, his scores went down to within the range of 60 to 90 ms.

During this time, George learned to ride a bicycle, which in the past had been very frightening and difficult for him to attempt. He made reasonable gains, and his parents continued to report gradual changes during the next year. Language gains were noted with regard to timing and speed of vocal output. His prosody improved but continued to be "a bit off." His handwriting and keyboarding improved in both speed and accuracy. His motor planning improved significantly, especially for sports skills. He was better with novel motor tasks but still had some difficulty.

At age 11, George returned for an assessment and intervention update. He was reassessed on the IM long form test, and his scores remained in the same range as when he had finished the IM program 2 years prior. George had been taking karate and was progressing well. He was discharged from his occupational therapy at home, although he still needed some work on postural control and balance. Neuropsychological testing identified challenges within the area of processing speed, and executive function issues were thought to contribute to difficulties in new learning and memory, as well as social problem-solving. He was given the diagnosis of social (pragmatic) communication disorder. Timing and rhythmicity in his vocal output, although improved, continued to be a problem. This is something that may be revisited in the future using IM adaptively in an individualized program that incorporates movement and some type of language demand or executive functioning demand.

CASE STUDY ■ MARTIN

Martin, who is 19 years of age, has received several services through many years, starting with Early Intervention at 2 years of age. He has a diagnosis of cognitive disability and has some autistic features. He has been seen for many years in an SI clinic. When he was 14 and had just started high school, his therapist started the IM program with him. At the time, he was anxious, impulsive, extremely rigid, had difficulty with problem-solving, and was slow to respond when asked a question or when confronted with a problem. He also had significant difficulty with postural control and motor planning as well as difficulty initiating familiar routines and actions such as getting dressed in the morning and packing his bag for school. Attention was a significant issue at school.

Martin started slowly in weekly sessions by learning the basic IM movement patterns, such as clapping with both hands at midline, tapping one hand on the thigh of the same side. As he learned the moves, the time on task was increased until he was able to consistently complete 2,000 repetitive sessions during approximately 45 to 55 minutes. Five years later, his therapist continues to use IM as part of his sessions but in unique and creative ways as part of a larger occupational therapy program. About every other week, 20 to 35 minutes of the occupational therapy session involves some form of IM. Most of the activities are done using a wireless trigger and a speaker instead of headphones.

One of his current activities involves walking backward on a treadmill, using the wireless hand trigger, alternating five hits on the opposite shoulder and then five hits on the opposite hip while doing visually presented math problems placed in different locations around the room (both numeric and short story word problems targeting addition or subtraction and money concepts). The target areas of this activity are mental endurance, focus and concentration, processing speed, postural adjustments and righting reactions, simultaneous intake and prioritizing of input, overall physical endurance, crossing midline, full body coordination, functional math, and timing.

Another activity involves standing on a Bosu in front of a table with Velcro cards with letters face down and a vertical Velcro surface behind. Using the wireless hand trigger to hit the opposite shoulder, Martin flips over all the cards with the other hand, and then puts them in alphabetical order (upper then lower case) on the board behind (trunk rotation). This requires visual discrimination and sequencing. Once the letter cards are in order, rapid recall cards are presented. For example, if a visually presented card reads "type of vegetable," Martin must think of a vegetable and use the letters to spell it out. Also, he is encouraged to problem-solve if he runs into difficulty, such as asking how to spell a word or what to do if he needs two of the same letter to spell a word. This activity is meant to address mental endurance, focus and concentration, processing speed, postural adjustments and righting reactions, overall physical endurance, crossing midline, full body coordination, timing, visual discrimination, recall, and problem-solving.

Martin enjoys opportunities to test his skills using the IM program and he is a motivated and eager participant. The point of the various IM activities is to access or activate different parts of the brain simultaneously with incoming information, and then integrate that information in order to produce the appropriate output actions (shift balance, calculate quantities, recall, find and sequence letters, all while maintaining his trigger beat). Throughout these types of activities, he typically scores within the range of 40 to 50 ms with 3 to 10 in-a-row (IARs) beats, hitting a target level of three in a row (a burst) 10 to 15 times during the duration of the activity, which is about 16 minutes in length. At times, he is given verbal cues to "stay off the reds" (indicating that he is very off beat) when he becomes distracted.

The school team, Martin's parents, and his therapist have noted overall improvements in processing speed, problem-solving, social interactions, reading fluency, fluidity of writing and keyboarding, speed and accuracy of writing, and better overall regulation. They also note that Martin learns from mistakes more quickly, is better at anticipating problems, has more confidence and success with novel motor actions, makes more spontaneous comments, and is less anxious. During the course of therapy, Martin also showed specific gains in timing, body awareness, visual-spatial awareness, left and right discrimination, multitasking, and bilateral coordination. When Martin started high school, he was enrolled in a life skill program in anticipation of eventually needing an adult day-care setting or at best a sheltered workshop. Now his school team feels that Martin will be able to work in a community setting with a job coach.

Concrete examples of the functional improvements seen include recognizing and anticipating the need to hold the door for somebody coming, waiting for someone to stop speaking before starting to speak, and anticipating what to bring to an outing without explicit instruction to change to boots, bring a wallet, and so on. Also, he is organizing himself so that it is done in a timely manner. Improved organization has increased his access to resources with improved ability to navigate the Internet (e.g., double clicking, using mouse or touch pad mouse). He is able to manage school materials more readily and use maps and reference points when moving about the community.

In addition to his IM activities, Martin continues to engage in open-ended, self-selected movement activities in a large SI gym and to engage in life skills and recreational and prevocational activities with his therapist. (Case study of Martin provided by Rose Heredia, MS, OTR/L.)

Section 5: Astronaut Training Program

Mary Kawar, MS, OT/L

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
Astronaut Training Program	• Integrated • Active and passive components	• Prescribed with some responsive components	• Traditional

Background

Beginning in the 1970s, Ayres developed clinical strategies for ameliorating vestibular dysfunction (Ayres, 1972). In more recent years, pediatric vestibular rehabilitation programs have addressed balance and vision stability issues intensively (Braswell & Rine, 2006; Casselbrant, Villardo, & Mandel, 2008; Cronin & Rine, 2010; Rine, 2009; Weiss & Phillips, 2006). The Astronaut Training Program (ATP) was built upon many years of mentorship by Dr. Ayres and Dr. Josephine Moore, years of clinical practice, and an increased awareness of the effectiveness of pediatric vestibular rehabilitation strategies. An expansion of the vestibular component of Ayres' original work, the ATP is a rotary and linear acceleration program that integrates sound-activated vestibular-visual processing for moving, looking, and listening. The ATP offers a systematic way to address vestibular-based issues.

The U.S. space program provided a real-world context for framing the ATP, because the training program to prepare astronauts for space travel closely parallels ATP therapeutic activities. The metaphor of climbing onto a space ship often captures children's imagination and helps dispel anxiety about the therapeutic activities. After the therapist does a "countdown," the child "blasts off into space" on an astronaut board (available from www.astronautboards.com) or on a suspended platform swing in order to bring back treasures from imagined visits to Mars or the moon. (Note: A scooter board does not work because the therapist cannot achieve precise rotation, and it is too short for side-lying.)

Rationale

The ATP reflects the neuroanatomical design and function of the inner ear, including all six peripheral vestibulo-cochlear receptors bilaterally and their connection, through the eighth cranial nerve, with CNS structures and pathways. A primary focus on the vestibular system, with secondary focus on the visual, somatosensory, and auditory systems (i.e., multisensory inputs), sets the ATP apart from most interventions that incorporate vestibular inputs (Schaaf & Lane, 2009), not placing specific emphasis on precise vestibular activation as a foundation for SI.

As a gravity receptor, the vestibular system instantaneously senses changes in head position in order to maintain stable visual images on the fovea of the retina and dynamic postural orientation and control of the body. Typically, the vestibular system is fully formed in the first trimester, able to elicit the expression of tonic vestibular reflexes in utero, and capable of supporting orientation of the head in space shortly after birth (Jeffery & Spoor, 2004; Rine, 2009; Weiss & Phillips, 2006). However, its influence on balance does not fully mature until late adolescence, whereas somatosensory and visual contributions to balance mature much earlier (Peterson, Christou, & Rosengren, 2006, Rine online vestibular course; Rine, Rubish, & Feeney, 1998). Some children who present with poor postural control or gravitational insecurity have underdeveloped or compromised vestibular function (Cronin & Rine, 2010). To maintain balance, they may rely on less efficient and more cognitively demanding compensatory strategies involving vision.

The ATP addresses vestibular connections at all levels, beginning with the profound interaction between sound and movement that starts at the receptor level, and including vestibular integration with all of the other sensory systems at multiple levels of the CNS. The vestibular receptors are afferently and efferently connected with the brainstem vestibular nuclei and with the archi-cerebellum that is exclusively devoted to vestibular processing. From the vestibular nuclei, there is two-way communication with many subcortical and cortical structures (Goldberg et al., 2012). See Chapter 4 (Structure and Function of the Sensory Systems).

Program Description

There are three distinct components to the ATP: (1) preparatory; (2) sound-activated, rotary; and (3) linear acceleration.

The preparatory component of the ATP can be considered an expansion of a sensory integration-occupational therapy (SI-OT) intervention because the child engages in fun, goal-directed movements that spontaneously orient the head in many different planes while executing a combination of rotary and linear head and body movements, at varying speeds, to activate as many receptors of the entire vestibular system as possible. These self-generated movements provide proprioceptive input to help modulate a potential vestibular overload. Participants are not coached for precision while engaged in these activities. Rather, they are encouraged to have fun and discover the joy of engaging in playful movements while accomplishing simple, purposeful acts, such as “rocking the bears” (see Figs. 18-7 and 18-8). To keep the activities dynamic and compelling, participants select their favorite music and create additional moves to complement those incorporated initially into the program. The preparatory protocol is a good starting point for vestibular activation as part of home, school, and clinic programs.

The second component of the protocol is the rotary program that incorporates focal and ambient sounds to keep individuals continuously informed that they are “here” in this “space.” Note that for this to occur, the sound source must be positioned near the child.

The individual maintains a specific orientation of the head while sitting or side-lying and being rotated by the therapist at a speed of one revolution every 2 seconds for up to 10 revolutions. Responses are carefully monitored so as to provide only as many revolutions as the individual can tolerate (with quick recovery) before proceeding with the next set. A full complement of rotations, if tolerated, includes three different head positions while rotating both counter-clockwise (CCW) and clockwise (CW):

1. Sitting with the head tilted forward 30 degrees (see Fig. 18-9) to activate the horizontal canals bilaterally
2. Side-lying on the right side with the head in line with the spine and tilted forward

FIGURES 18-7 and **18-8** Therapist and child rock the bear back and forth to spontaneously and repeatedly alter the orientation of head in space. *Photos courtesy of Mary Kawar.*

30 degrees and turned 45 degrees to the right of midline, toward the support surface (Fig. 18-10) to activate the right superior and left posterior canals

3. Side-lying on the left side with the head in line with the spine and tilted 30 degrees forward and turned 45 degrees to the left of midline, toward the support surface to activate the left superior and right posterior canals.

Rotation in the sitting position induces reflexive horizontal perirotary nystagmus and post-rotary nystagmus (PRN) responses, which are alternating rapid, resetting eye movements (saccadic reflexes) and slow following eye movements (smooth pursuit reflexes) involving the medial and lateral rectus muscles. Immediately after the PRN has stopped, the child does the same eye movements voluntarily while viewing a penlight that the therapist moves in conjunction with a soundtrack, thus coordinating vision and sound. Rotation in the side-lying positions induces reflexive vertical peri- and post-rotary nystagmus responses involving the superior and inferior rectus muscles and the superior and inferior oblique eye muscles. Volitional vertical saccades and smooth pursuit movements timed to music are elicited following the reflexive eye movements.

In the rotary protocol component of the ATP, an astronaut board, which does not require a suspension system, is used for rotation. The board can be easily carried from one setting to another, is close to the floor for safety, and emulates the "blasting off into space" theme. This

FIGURE 18-9 Head vertically aligned with spine and tilted in 30 degrees of flexion. *Photo courtesy of Mary Kawar.*

FIGURE 18-10 Head in line with spine with 30 degrees of neck flexion and turned 45 degrees to the right of midline. *Photo courtesy of Mary Kawar.*

component is therapist directed, although it does spark the child's imagination. Activation of the vestibular-ocular reflex during and following rotation is thought to provide a foundation for the child to subsequently generate volitional saccadic and smooth pursuit eye movements.

Once all rotations have been completed, the child sits up and does a brief oculomotor "wrap up." This includes volitional saccades and pursuits in all directions, near-far convergence and divergence, stabilizing eye focus on the visual target while moving the head, and sustaining visual focus on a stationary midline target while monitoring the peripheral visual field for moving visual targets. Compelling visual objects are used as visual targets, and a lively soundtrack helps integrate the vestibular, somatosensory (support for head and trunk alignment and stability), visual, and auditory aspects of performance.

The most important guideline for rotary activation is to avoid overloading the system. The objective is to provide the just right amount of rotary stimulation to allow quick recovery and lay a comprehensive vestibular-somatosensory foundation for subsequent adaptive engagement with people, objects, and events. Individuals who are hypo-responsive to vestibular activation can usually tolerate a significant amount of intense acceleration. Even so, they may be overly sensitive because of lack of exposure to vestibular acceleration in side lying. When vestibular function has been permanently compromised (for example, because of congenital anomalies: refer to case 4) other sensory systems need to be trained to take over the compromised vestibular function.

Individuals who are hypersensitive to vestibular activation have been found to increase tolerance most successfully by frequent exposure to small, gradually increasing amounts of rotary movement. When an individual person experiences an adverse response to rotation (e.g., dizziness, nausea, pallor), the therapist immediately engages the child in rigorous proprioceptive activation through resistive activities (e.g., wall push up) to help inhibit vestibular overload. The rotary protocol should always be done at the beginning of a session, followed by inviting linear activities with scooter boards, gymnastic balls, or a variety of suspension equipment that entails emphasis on proprioceptive activation to modulate vestibular activation.

The third component of the ATP focuses on linear movements. The ATP includes a wide variety of linear acceleration activities that, together with strategic placement of visual and auditory targets, encourages spontaneous changes in head position. Facilitating several different head positions supports awareness of head position in space under all conditions. These linear activities are often supported by music that matches the timing and rhythmicity of the requisite movements. Research has documented that sound-enhanced movement increases muscle strength and endurance and improves timing and rhythmicity (Thaut, 2007).

(Note: This program is described in greater detail in a booklet/CD combination by Kawar and Frick [2005] and in a chapter by Kawar [2005].)

Relationship to Sensory Integration and Occupation

Aspects of the preparatory (first component) and linear acceleration (third component) protocols of ATP are closely related to SI-OT intervention. They involve active engagement in specific, whole-body, goal-directed activities that provide enhanced vestibular-auditory-visual inputs. Many of the suggested activities are typical of those seen in SI-OT clinics. The rotary protocol (component 2) departs from SI-OT because the therapist rotates the child. However, although the input is provided passively, the child is actively stabilizing the body, listening to the focal and ambient soundtrack, and responding visually to stationary and moving targets. Some children enjoy learning how to spin themselves independently with optimal head positioning. The therapist also directs the follow-up volitional eye movements that are a part of all ATP protocols, setting these aspects apart from SI-OT interventions.

Expected Benefits

The ATP utilizes several strategies designed to ameliorate vestibular challenges through adaptation (to reset the system for improved gaze stability and postural control), habituation (to diminish or alleviate motion sickness and dizziness), and substitution (to compensate for vestibular anomalies or loss). Precise vestibular activation provides a solid foundation for supporting, integrating, and enhancing the combined contribution of all the sensory systems to optimal engagement in life occupations. Cronin and Rine (2010) emphasized how a comprehensively designed vestibular activation program can significantly enhance a child's performance in terms of development, learning, postural alignment and control, and confidence in achieving age-appropriate skills. Anecdotal results consistent with Cronin and Rine's statement are reported from using the ATP in conjunction with an SI therapy program. No research has investigated ATP directly, and rigorously designed studies are needed to document its effectiveness.

Target Populations

The ATP may be used with children and adults throughout the lifespan, starting as young as 1 month of age. These individuals may demonstrate difficulties with vestibular-somatosensory, vestibular-visual, and vestibular-auditory integration associated with movement deprivation, emotional trauma, gravitational insecurity, dizziness, car sickness, and aversion to head movement, among others.

Training Recommended or Required

Therapists using the ATP must be competent in essential clinical assessment, reasoning, and application skills related to SI, vestibular-visual functioning, and the ATP in order to be able to adapt the program to meet the unique needs of each individual. It is recommended that occupational therapy practitioners have at least 1 year of clinical practice before becoming trained in the ATP. Certification in the Sensory Integration and Praxis Tests (Ayres, 1989), including in-depth theory, is also recommended to provide a foundation in SI assessment and intervention before taking formal training in this program.

Formal training in the ATP is best achieved by taking the 2-day continuing education course entitled Astronaut Training: A Sound Activated Vestibular-Visual Protocol (https://vitallinks.com/course/astronaut-training/) through Vital Links. This experiential training workshop includes the Astronaut Training booklet and CD. Advanced ATP training to become a preferred provider is being developed to further ensure that the ATP is being utilized competently and responsibly. Individuals desiring to use the ATP also should consider the "Eyesight to Insight" continuing education course (https://vitallinks.com/course/eyesight-to-insight/) sponsored by Vital Links to develop proficiency in visual-vestibular assessment, integration, and intervention techniques. Pediatric vestibular rehabilitation courses are another related avenue for continuing education.

Case Examples

Next are four short case vignettes describing the use of the ATP for different presenting concerns. It is important to keep in mind that each child is unique, and this program lends itself to individual adaptation based on needs, tolerance, and goals.

CASE STUDY ■ RITA

An adaptation frame of reference to enhance the efficiency of bilateral vestibular processing was used with Rita, a 7-year-old girl with a history of chronic right ear infections and right-sided vestibular hypo-responsivity. Rita demonstrated asymmetrical vestibular processing as seen by an 18-second PRN response when rotated to the left and no observable PRN when rotated to the right. She presented with poor balance as well as handwriting and reading difficulties. Rita could not maintain visual clarity when an object came within 6 inches of her eyes.

Rita was started on two 60-minute weekly outpatient occupational therapy sessions and a daily preparatory ATP home program, incorporating Rita's music choices to accompany the movements, which she referred to as dancing. The rotation protocol of the ATP, including volitional eye movements and the soundtracks, was completed at the start of each session. For the remainder of these sessions, Rita selected various linear acceleration activities that incorporated interaction with visual and auditory targets that she strategically placed to facilitate spontaneous changes in head position while moving through space on equipment (e.g., scooter board, carpet skates, suspended hammock).

After the first 2 weeks, the rotation protocol of the ATP replaced the preparatory program at home. Within 3 months, Rita no longer demonstrated the right-side hypo-responsivity and had a right PRN of 13 seconds' duration, consistent with her left-side PRN response, suggesting symmetrical vestibular processing. Moreover, Rita's handwriting was increasingly legible, reading fluency was beginning to emerge, and her parents reported that she had finally achieved her goal of being able to ride a bicycle. At this point, they pursued a vision assessment.

CASE STUDY ▪ ROBBIE

Adaptation strategies were also used with Robbie, a 5-year-old boy with autism whose favorite activities were standing and spinning to his right and spinning objects. After a thorough evaluation, it was hypothesized that Robbie was trying to provide himself with sufficient vestibular-visual activation to meet his sensory needs because his self-regulation appeared better after spinning himself or objects. In addition to his once weekly clinic sessions, a daily home program utilizing rotary and linear activities with the astronaut board and the scooter board was initiated to activate all vestibular receptors precisely.

Within 1 week, Robbie's perseverative spinning was markedly reduced. Within 5 weeks, he had ceased spinning behaviors, provided that he maintained a movement-rich sensory diet.

CASE STUDY ▪ GEORGE

Habituation strategies were incorporated into 10-year-old George's intervention program. George was referred to occupational therapy because of severe carsickness, which limited him to riding in a car for only a few blocks before vomiting. Initially, in clinic-based occupational therapy, he could tolerate and quickly recover from a preparatory movement activity that involved standing and quickly turning himself around for one revolution CW, followed by touching the wall and visually fixing on a target and then rotating CCW and again touching and looking. All other attempts at rotary movement activities resulted in nausea. However, he could tolerate linear movements on a scooter board.

After 2 weeks of twice-daily self-spinning at home, he had increased his tolerance for rotary movement to 10 revolutions each way with quick recovery and was able to begin the ATP astronaut board rotational protocol. During a 6-week period of doing the rotary protocol two to three times weekly at home and twice weekly in the clinic, George could achieve quick recovery following rotation in all positions (upright and side lying). He was able to enjoy participating in movement activities that were of interest to him and no longer experienced carsickness, even while reading in the car.

CASE STUDY ▪ PAGE

Page was a 4-year-old with a congenital anomaly of the vestibular receptors manifested by the presence of only fragments of semicircular canals bilaterally. When first seen, she had received occupational and physical therapy for more than 3 years, but she was unable to walk independently. A substitution strategy was initiated by adapting the ATP rotary protocol to focus on enhancing somatosensory, visual, and auditory inputs to compensate for her lack of vestibular processing capability.

Page loved spinning and quickly learned how to spin herself by pushing on a vertical pole that was positioned close to the astronaut board and stabilized by the therapist. The astronaut CD was also positioned close to the board so that the sounds could enhance auditory awareness of her place in space as well as her sense of the space that she was spinning in. She was able to tolerate a twice daily, self-administered rotary acceleration program with eyes open at the rate of 1 to 2 revolutions per second for at least 10 repetitions both CW and CCW with no adverse effects. The therapist or the mother held the penlights so that she could do the visual wrap-up program after she completed the rotations.

Page's self-spinning seemed to heighten her proprioceptive awareness in order to maintain her balance on the board (increasing extension of the left side of the body when turning to her left and increasing right-sided extensor activation when turning to her right). Increased tactile awareness facilitated weight shifting on the board. Peripheral visual flow was activated by the fast movement on the board with her eyes open, and focal vision was enhanced by repeatedly sighting the pole to push on it and by performing the oculo-motor wrap-up activities.

One month after initiating the ATP, Page took her first steps, suggesting increased efficiency of somatosensory, visual, and auditory processing to compensate for a lack of vestibular function.

Section 6: Infinity Walk Training

Mary Kawar, MS, OT/L

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
Infinity Walk Training	• Integrated • Active	Prescribed	Traditional

Background

Infinity Walk (IW) training was first developed by Deborah Sunbeck, PhD, in 1991 for use primarily in special education. Sunbeck's books (1996, 2002) and workshops have helped to introduce the application of the IW program to other professions, including occupational and physical therapy. The IW program includes several strategies, with varying degrees of complexity that have emerged through time. The basic IW program is the focus of this section.

The IW contributes to a repertoire of novel, compelling, versatile therapeutic strategies. It can be utilized in any environment with minimal props and expense. An imaginative therapist will discover that it affords unlimited options for adaptation. One of its great advantages is that many physical, cognitive, and social experiences can be incorporated through time to sustain interest. The IW lends itself to group participation as well, so that it can be used with family members and classmates for home and school-based programming.

Rationale

IW is a strategy for enhancing multisensory processing and bilateral motor coordination. IW activates the upper and lower extremities in conjunction with simultaneous rotation or counter-rotation of the shoulder girdle and pelvis while simultaneously eliciting continuous head movements from side to side so as to engage the eyes and ears with a stationary target.

Program Description

The IW involves walking continuously first CW, then CCW, around a figure eight (i.e., infinity symbol) pattern. Simultaneously, the participant looks at, listens to, or interacts with a strategically placed stationary target (e.g., person, TV, video, or other object). The target is positioned perpendicular to the crossover point between the two circles of the figure eight pattern and at an optimal distance for effective interaction between the participant and the target. Refer to Figures 18-11 and 18-12 for an activity example of a child playing darts while walking along the infinity pattern.

The participant selects the target so that it appeals to his or her interests. It may be helpful to change the target during the walk to extend the walking time and thereby enhance the benefits.

Several aspects of function should be considered when implementing the IW:

- The therapist may need to guide the participant from behind to keep him or her on the path. It is *not* recommended to mark a line on the floor, because then participants are tempted to watch the line rather than focusing on the stationary target while walking. Looking at the path also keeps the body in midline and symmetrical and precludes the unfolding of the many other desired movements.
- Walking the IW promotes continuous recalibration of the relationship of the head, neck, and body to keep the eyes and ears oriented on the focal target. Each step along the path requires a slight shift in head position in order to sustain focal attention on the target. These movements of the head create an opportunity for the individual to process information continuously with the eyes and ears all the way from the extreme left visual and auditory field through the midfield and on to the extreme right visual

FIGURES 18-11 and **18-12** The dartboard visual target and the recorded music are positioned perpendicular to the crossover point of the two circles at an appropriate distance from the path. A fanny pack is used to transport the darts so that both arms are free. The tape on the floor is only used to illustrate the path for the reader. It is not used with the activity.

and auditory field. The thought is that the eyes and ears become integrated with dynamic head movements for efficient visual and auditory orientation and processing in all life tasks.

- Walking the IW involves subliminal processing of sights and sounds in the surroundings to promote orientation in space. This frees the individual to sustain focal cognitive engagement without needing to consciously attend to where the body is in space.
- Changing between walking the CW circle and the CCW circle involves a reversal of the direction of rotation between the shoulder girdle and pelvis and a gradual transition into and out of symmetry at the midpoint of the circles. This dynamic interplay between the upper and lower trunk enhances body scheme and supports bilateral integration and praxis.
- When walking around the CW circle, the left leg must take longer strides, followed by even stride length at the midpoint and then longer strides with the right leg when negotiating the CCW circle. These constant, subtle changes in stride length, in conjunction with weight shift demands, provide somatosensory input to enhance body scheme and balance and support the development of praxis.
- Swinging the arms in conjunction with shoulder movement and opposite pelvic movements helps elicit trunk rotation and establish a foundation for functional bilateral skill development.
- All hand activities are placed at the crossover point and at an optimal location. Activities that have proven to be appealing include dropping coins in a piggy bank, eating a snack by picking up pieces of food from a plate, putting a piece in a puzzle, and stacking cones.

Special considerations and modifications of the IW include:

- Keeping the activity demands realistic to ensure success. Simply walking along the path can take one's full concentration initially. The more interesting the focal target, the more compelling it will be for the child to attempt to attend to and engage with it while walking.
- Positioning a CD player at the focal point to provide music when the chosen activity does not include sound.
- Changing the placement of the focal target (e.g., high-low and near-far) to alter focal orientation and visual demands.
- Using "infinity riding" to enable non-ambulatory individuals to be transported along the path. A caregiver can carry an infant face forward or place the infant in a stroller. One child can pull another in a wagon. A child can be in a wheelchair, riding a tricycle, or using a scooter board.
- Guiding participants to negotiate the path in different ways, such as walking backward, jumping, hopping, crawling, skipping, or doing animal walks. Many of these variations can be accomplished while the child is multitasking with flashcards being held by the therapist at the focal point or having a dialogue with the therapist about a movie, what happened at the playground, and so on.

Relationship to Sensory Integration and Occupation

The IW can fit into the SI frame of reference when a therapist implements it in a manner consistent with the theory and principles of OT-SI intervention. As such, IW has an indirect relationship with occupation.

Expected Benefits

IW directly addresses the development of bilateral integration and postural control. The repetitive nature of IW lends itself to developing automaticity in basic movements. Efficacy studies are needed to document the favorable anecdotal evidence reported by therapists who have utilized IW as an integral component of OT-SI intervention.

Target Populations

IW is a self-paced method that is appropriate for children and adults of all ages. When children are too young or are physically incapable of walking, they can do infinity riding while turning their head and trunk as well as incorporating their upper extremities with the visual and auditory activity that is serving as the point of focus. Higher functioning participants can do multitasking with high-level cognitive processing and simultaneous, adaptive management of the body in space.

Training Recommended or Required

No training is required to use the IW program; however, there are several helpful resources. Sunbeck's (1996, 2002) two books describe the theoretical rationale and creative process that culminated in developing and implementing the IW program. She currently offers a webinar entitled "The Infinity Walk Method: A Developmentally Progressive and Integrative Systems Approach to Clinical Treatment" (Sunbeck, 2013).

CASE STUDY ■ KEVIN

Kevin, an intelligent 9-year-old boy with a 2-year delay in reading ability, immature bilateral motor coordination, and poor self-esteem, came very reluctantly for OT-SI intervention at the request of his parents. He was being pulled out of class for a reading resource program. Before his initial occupational therapy visit, he had received 6 months of developmental optometry for correction of right exotropic strabismus as well as a year of private tutoring with a reading specialist. He described himself as a "klutz" and stated that he hated to read. Although vision therapy had recently improved his binocular control, he had spent several years avoiding sports, socializing with peers, and reading.

Kevin took a liking to the IW after the therapist introduced him to the idea of using a water pistol with a bull's eye target painted on a plastic apron worn by the therapist. It allowed him to channel his frustrations and detracted him from thinking about how challenging it was for him to walk the path. He often resorted to side-stepping because he seemed stuck in symmetrical movements and had minimal body scheme awareness. Trunk stiffness impeded lower extremity mobility and the ability to keep his feet aligned and pointed in the direction of the path's CW and CCW curves. He sometimes missed crossing over at the mid-position but never missed an opportunity to squirt the water gun, sometimes hitting the therapist instead of the apron. He was encouraged to alternate hands with the water pistol to free his head and trunk movement and gain further arm movement and eye-hand coordination.

After two sessions, Kevin could stay on the path through the crossover point, although his performance was still immature. He began choosing a wider range of IW activities with increased sensory, motor, and cognitive demands. An IW home program was started for 10 minutes twice daily while watching television. This was very rewarding for him, because TV time was rarely permitted.

Each week, Kevin demonstrated further reduction in postural rigidity and greater rotation and counter-rotation of the trunk accompanied by rhythmic extremity movements. He consistently stayed closer to the path. Frequent engagement in the IW home program was largely responsible for the gains. He became eager to engage in cognitive IW activities, including reading words from flashcards he made. The therapist manipulated the cards while they discussed definitions, putting the words into sentences, and so on. As his bilateral coordination and praxis improved, he also became more fluid and quick in his reasoning and communication skills.

After approximately 2 months of occupational therapy using IW, Kevin reported that he had begun to read for pleasure before going to sleep and that his resource teacher had moved him up one grade level in reading. He chose to join a therapeutic sports-oriented group with two other boys to start building his ball skills. Through the IW he had found his path to increasing self-esteem and rewarding achievement of goals that he had previously thought were beyond his reach.

Section 7: Therapeutic Listening®

Sheila Frick, OTR/L

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. nontraditional
Therapeutic Listening®	• Single system • Passive	Prescribed	Traditional

Background

The use of sound-based interventions emerged in the 1950s when Dr. Alfred Tomatis created the Electronic Ear, the basis for the Tomatis Method (Tomatis, 1996). Initially, Dr. Tomatis treated patients with auditory processing and learning difficulties and, later, children with autism. Other sound-based techniques, such as Auditory Integration Training, developed from the Tomatis Method.

In the early 1990s, a small group of occupational therapists trained in SI began incorporating sound-based approaches into 2-week intensive intervention protocols based on an SI frame of reference. The first published case studies using this approach (Frick & Lawton-Shirley, 1994) showed promising results in many areas typically addressed in SI therapy (e.g., sensory defensiveness, gravitational insecurity, and praxis). Although participants appeared to benefit from the interventions, there were several barriers. Participation required extensive time and financial resources and necessitated intervention in a clinic setting. To minimize the barriers, Therapeutic Listening® was developed based on extensive clinical experience with SI and auditory interventions specifically for use in a variety of settings and with a large population (Frick & Hacker, 2001).

Rationale

Ayres (1972, p. 123) described the vestibular system as providing a "unifying and coordinating role in relation to all other sensory input" and acting as a key integrator in sensory processing. Because of the interaction of the vestibular, visual, and auditory systems, we are able to move, explore, and engage with people and objects in the three-dimensional environment. When individuals experience SI challenges, the vestibular system—which has direct connections to the auditory system—is often a target of intervention.

The vestibular and auditory systems are intimately connected, both anatomically and neurologically. Both systems are housed within the bony structure of the inner ear and function via hair-like receptors moving in fluid-filled canals. Both systems share the eighth cranial nerve, which sends neurological impulses to the CNS—crossing paths and exchanging information at multiple junctures in the cerebellum, brainstem, and cortex. Research conducted by Emami and colleagues (2013) identified the stimulation of the saccule in response to high-intensity low-frequency sounds. Furthermore, the saccule can support the cochlea in hearing in noisy environments (Emami et al., 2013). Because of these intimate connections, auditory interventions such as Therapeutic Listening® are thought to support the sensory processing that underlies occupational performance and function.

A key component of Therapeutic Listening® is specialized electronic modification of specifically recorded music, designed to highlight aspects of the sound spectrum and initiate an **orienting response** to salient features of the environment (see Fig. 18-13). Orienting is a subcortical action in response to novelty in the

FIGURE 18-13 A key component of Therapeutic Listening® is specialized electronic modification designed to highlight aspects of the sound spectrum that initiate an orienting response to salient features of the environment. *Photo courtesy of Sheila Frick.*

FIGURE 18-14 Therapeutic Listening® is a sound-based intervention often embedded into intervention based on the principles of sensory integration. *Photo courtesy of Sheila Frick.*

environment. When individuals detect and orient to novelty, they display characteristic behavioral patterns: stilling of the body, head turning, and visual search (Siddle, 1983). They also experience physiological changes in heart rate, respiration, and pupillary dilation (Frick & Young, 2012). Orienting responses ultimately influence the autonomic nervous system (ANS) through neural pathways in the limbic system, reticular formation, and other subcortical areas.

Orienting precedes adaptive behavior. In asserting that orienting is a pre-adaptive response, Ayres (1972) paved the way for an underlying assumption of Therapeutic Listening®: facilitating orienting may "prime" the approach behaviors that precede adaptive responses (Wilbarger & Frick, 2011).

Another cornerstone of Therapeutic Listening®, *rhythm,* also appears to have far-reaching influences on the nervous system—especially motor networks (Bengtsson et al., 2009). Thaut and colleagues (1992) have extensively investigated the relationship between music, rhythm, and motor output. In one study, they found that auditory rhythms immediately improved gait patterns in individuals with neurological injury (Thaut, Kenyon, Schauer, & McIntosh, 1999). Using electromyography (EMG), Thaut and colleagues (1992) demonstrated that rhythmic input facilitates motor unit recruitment patterns—ultimately influencing motor control, coordination, and performance. Type and quality of rhythm influence the motor system through entrainment with motor responses (Thaut & Abiru, 2010). The musical rhythms in Therapeutic Listening® are specifically selected to match individuals' needs and support targeted therapeutic outcomes.

Program Description

Therapeutic Listening® is a sound-based intervention often embedded into a therapeutic approach based on the principles of SI (see Fig. 18-14). Therapeutic Listening® involves an individualized intervention progression in which recorded music is selected based on an individual's unique clinical picture and used within a variety of intervention settings. Therapeutic Listening® includes a wide range of music, precisely engineered to utilize rhythm, facilitate orienting response, and support adaptive behaviors. During a Therapeutic Listening® progression, children listen for 30 minutes, twice per day, and rotate through an assortment of music. Because Therapeutic Listening® is highly individualized, length of participation varies, on average, from 3 to 6 months. However, many individuals continue using Therapeutic Listening® as a part of an ongoing sensory diet.

Relationship to Sensory Integration and Occupation

Therapeutic Listening® is thought to 'prime' an individual for adaptive responses; therefore, it is often utilized within a therapeutic approach utilizing interventions based upon the principles of SI theory. This joint interaction is meant to facilitate organization and dynamic engagement with the environment as a foundation for occupational participation.

In her early work, Ayres (1972) addressed the relationship between the auditory and vestibular systems. Although she never directly discussed the use of enhanced auditory input, we think of Therapeutic Listening® as an expansion of Ayres' original theory. However, when Therapeutic Listening® is used in the absence of any demand for adaptive interaction, it represents pure sensory stimulation and falls outside the construct of SI. Therapists commonly report changes in child factors and performance skills that influence activities of daily living, instrumental activities of daily living, school and work, and other occupational domains.

Expected Benefits

Therapeutic Listening® used within an SI therapy perspective can increase effectiveness for individuals with sensory integrative dysfunction. A wide range of functional improvements associated with Therapeutic Listening® has been documented in research. In 2005, Vital Links conducted an international survey of 1,343 practitioners trained in Therapeutic Listening® (Frick & Young, 2012). Practitioners reported improvements in attention, self-regulation, sensory modulation, sound sensitivities, sensory defensiveness, focus, energy level, ease with transitions, and mood. In addition to supporting *specific* functional gains, practitioners reported that Therapeutic Listening® appeared to speed up the rate of improvement in *overall* (general) goals.

Empirical results are consistent with gains observed by practitioners. Researchers examining the effectiveness of Therapeutic Listening® have employed several designs: repeated measures, pretest and posttest, case study, and qualitative phenomenological approach. Most participants have been preschool or elementary-aged children identified with developmental disabilities or sensory processing challenges. Outcome measures include both parent and teacher report and standardized assessments. Studies have taken place at home and at school.

Hall and Case-Smith (2007) investigated the effects of Therapeutic Listening® and a sensory diet for elementary-aged children with developmental disabilities. They wrote, "participants demonstrated remarkable improvement in behaviors that reflected [poor] sensory processing" as measured by the Sensory Profile (p. 214). They demonstrated significant gains in the Visual Perception subtest of the Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery-VMI), and in handwriting (measured by the Evaluation Tool of Children's Handwriting). Parents also reported improvements in attention, social interaction, ease with transitions, self-awareness, sleeping, and listening to and following directions.

Studying a preschool population, Bazyk and colleagues (2010) assessed the effectiveness of Therapeutic Listening® on a variety of school performance domains.

Results from pre- and post-test assessments showed significant improvements in visual motor, fine motor, language, nonverbal intelligence, and social skills. In addition, parents and teachers reported significant progress in attention and communication skills, ability to follow directions, participate in group activities, and complete activities of daily living.

Wink, McKeown, and Casey (2017) conducted a qualitative study examining parents' experiences and impressions of use of Therapeutic Listening® as part of a home program for their children with sensory processing difficulties. The findings from parent interviews were transcribed and analyzed for key themes. Researchers identified critical subthemes following Therapeutic Listening®, including: reductions in their child's level of anxiety and distress; all parents acknowledged their child was "calmer," and noted subsequent improvements in family life and participation in activities of daily living and social interactions. Current research provides preliminary support for Therapeutic Listening®. However, rigorous studies are required to validate its effectiveness and support its use with broader populations. Future research should include control groups and larger samples that vary in age and diagnoses or difficulties. As Hall and Case Smith (2007, pp. 214–215) wrote, "Given the robust effects [of Therapeutic Listening® on behavior], additional measures should be incorporated in future studies."

Target Populations

Therapeutic Listening® is most often utilized with children older than 2 years of age. However, when monitored by a trained provider who uses an adapted protocol (i.e., modulated music is not played through headphones), Therapeutic Listening® can be appropriate for children under 2 years of age.

Individuals with a variety of difficulties or diagnoses may benefit from Therapeutic Listening®. Most often children display abnormal responses to sensation (e.g., sounds, touch), poor attention and modulation of arousal, difficulty following directions, poor ability to transition or deal with changes in routine, poor timing and sequencing of movements, and difficulty interacting with peers. Common clinical diagnoses include sensory integrative dysfunction, ASD, and ADHD. Therapeutic Listening® is contraindicated for individuals with auditory evoked seizures or schizophrenia.

Training Recommended or Required

Before implementing Therapeutic Listening®, therapists are required to complete a basic training course entitled "Listening with the Whole Body" offered through Vital Links, a continuing education company (Vital Links, 608-270-5424, www.vitallinks.com). Continued mentorship and training beyond the 2-day basic course is encouraged. The modulated music and specialized headphones required for Therapeutic Listening® may be purchased through Vital Sounds, following completion of the 2-day basic training (Vital Sounds, 6613 Seybold Rd., Suite E, Madison, Wisconsin 53719, www.vitalsounds.com).

CASE STUDY ▪ CHRISTOPHER

At 5 years of age, Christopher displayed sensory processing difficulties that seemed to underlie difficulties with participation at home and in the community. These difficulties included poor emotional regulation, anxiety around movement and gravitational insecurity, and defensive responses to sensory input.

Christopher displayed extraordinary difficulties with emotional regulation. His mother described his "meltdowns" as lasting for hours and occurring up to three times daily. Once Christopher reached an elevated emotional state, it was extremely difficult to calm him. These regulation challenges influenced Christopher's life and prevented him from attending social activities.

Christopher also demonstrated gravitational insecurity, which resulted in significant anxiety around activities where his feet were off the ground or that required changing levels (e.g., stairs, escalators, and playground climbing equipment). Once at a birthday party, Christopher followed a friend up a slide ladder. After climbing three rungs, he began screaming at the top of his lungs. He was so frozen with fear that his mother had to physically assist him off the ladder—one limb at a time.

Christopher also displayed tactile defensiveness, which influenced dressing, bathing, and eating. He did not enjoy having his hair or face washed and demanded that his clothing be "just right." Christopher was very particular about textures. He avoided touching grass or sand, could only tolerate certain shoes, and would only wear one brand of socks. Christopher was also a very picky eater and had an extremely limited diet. One evening, when Christopher did not enjoy the dinner being served, he erupted into tears and ran to his room. He was inconsolable for hours.

Christopher's sensory defensiveness was also evidenced in response to sounds. When riding in the car, he could only tolerate increasing the radio volume if he controlled the dial. If his mother adjusted the volume, Christopher would erupt in a tantrum. Because the family lived near an airport, they often heard planes flying above. When this occurred, Christopher became extremely upset and quickly covered his ears to dampen the sound. He also became distressed by low frequency sounds, such as lawnmowers.

In addition to reported functional challenges, clinical observation revealed difficulties with sensory processing. Initially, Christopher's postural and ocular skills appeared within normal limits. However, he held his breath and stiffened his body in response to motor challenges, suggesting some difficulty.

Therapeutic Listening® proved essential to reducing anxiety associated with gravitational insecurity and sensory defensiveness. During his first experience with Therapeutic Listening®, Christopher demonstrated a strong orienting response. His body became very quiet and still, and his breath deepened. This orienting reaction appeared to prepare Christopher for activities that followed in the clinic because he conquered previously challenging activities and was better able to modulate his arousal to meet the physical and emotional demands of the activities.

Christopher was treated biweekly during his 3 months in the clinic and at home. Initially, Therapeutic Listening® comprised his home program; after a time, the Wilbarger Therapressure Program ™ and precise vestibular activities were added. At his final session, Christopher excitedly announced how he had recently "flown" down a huge slide at a local water park and was able to climb a giant ladder at the local hardware store. Christopher's explosive tantrums ceased. When talking about his time in the clinic, Christopher described his experiences as "magical."

Section 8: Applying Suck/Swallow/ Breathe Synchrony Strategies to Sensory Integration Therapy

Patricia Oetter, MA, OTR/L, FAOTA ■ Eileen W. Richter, MOH, OTR/L, FAOTA

PROGRAM	SENSATION	APPROACH	SETTING
	• Integrated vs. single system • Application: active vs. passive	• Responsive vs. prescribed	• Traditional vs. Nontraditional
Suck, Swallow, Breathe	• Integrated • Active	Prescribed	Both

Background

In the late 1970s, Patti Oetter's practice included Phillip, a 3-year-old boy with Down syndrome. Similar to many of the other children on her caseload, Phillip presented with vestibular, postural, and ocular-based issues; oral motor issues; and irregularities in depth, rate, and rhythm of his respiratory patterns. Phillip engaged in compensatory strategies to support his function, such as using respiration (blowing) to change vestibular and postural outcomes and sucking, biting, and chewing during vestibular-based activities. Patti discussed these intriguing behaviors with Dr. Ayres at one point and Ayres told Patti to continue to study the suck/swallow/breathe synchrony (SSB) because it was "the seat of sensory integration" (Ayres, A. J., personal communication). Patti took that advice and in collaboration with several colleagues has seen improvements.

Rationale

Because of the survival nature of the SSB synchrony and the prodigious display of SSB synergistic behavior in infancy, SSB has been studied extensively, from embryonic development throughout the lifespan. The significance of SSB synergistic development has also been studied extensively, including:

- The use of nonnutritive sucking to self-regulate (Pickler, Frankel, Walsh, & Thompson, 1996)
- The bonding for social development that is established during feeding (Montegue, 1986)
- Ocular-motor coordination (Kalnins & Bruner, 1973); refinement of sound through trigeminal and facial nerve to the stapedius and tensor tympani muscles of the inner ear; neck and head control that develops as use of the SSB synergy integrates with brainstem functions (Barlow, 2009)
- Mouth and hand function (Gentilucci & Campione, 2011; Rochat, 1993).

The face and mouth are some of the most sensory-rich areas of the body. The evidence for SSB influence throughout development may be inferred through observation and neuroanatomical research showing that the components of sucking, swallowing, and breathing operate synchronously, rhythmically, and independently. Half of the cranial nerves are directly related to oral sensorimotor and respiratory functions (CN V, VII, IX, X, XI, XII). Complex information traveling on these cranial nerves connects with numerous structures throughout the nervous system. These include cranial and spinal nerves, medulla, pons, brainstem, cerebellum, thalamus, and, in turn, cerebral hemispheres. These neurological connections underpin SSB and many aspects of development (see the SSB Model; Fig. 18-15).

Anatomically, neurologically, and biomechanically, the functions of the SSB synchrony, which evolve to a muscle synergy through functional use, have direct and indirect influences on many aspects of life and human development. As Figure 18-15 illustrates, the influences are neither linear nor mutually exclusive. The interrelationships also indicate that we can influence the outer rings by addressing the SSB or its specific components. Bringing arousal into optimal range, for example, by using SSB strategies for self-regulation (i.e., sucking on a straw or chewing a pen top) may also influence engagement, postural and motor organization, voice, and articulation (i.e., first ring—postural or psychosocial functions; second ring—vision or communication; third ring—attention, postural mechanism, social emotional development, speech).

As each component develops and refines, that refinement contributes to the development and elaboration of other components. Early in development, suck and gnaw, cry, and voice on breath are the only oral motor or respiratory skills that can influence the synergy. Later, bite, crunch, chew, and lick, followed by suck, seal, vacuum, and swallow, become additional ways to access and activate the synergy.

Dr. Ayres wrote, “Any major neural structure receiving sensory input from many sources is apt to have widespread influence over the rest of the brain. Multiplicity of input also usually means convergence of input and thereby integration of input. The brain stem and thalamus are good examples of these principles” (Ayres, 1973, p. 82). The influence of the SSB is an excellent example of Ayres’ statement. Consider this action: When a nursing infant looks up from the breast, the muscles of the inner ear contract to prepare for the sound of the human voice. This seemingly simple act requires massive integration of all 12 cranial nerves (Brownlee & Watson, 1997).

Because the SSB synergy is so broadly integrated throughout the brain and spinal cord architecture, our model suggests that it impacts many areas common in children with sensory integrative dysfunction, including modulation, postural control, praxis, and so on. On the postural side of function, any deficit in posture is associated with a concurrent deficit in respiration (and vice versa), because the neurology, muscles, and structures are the same for both. This provides a strong indication that SSB should be considered in children with postural dysfunction.

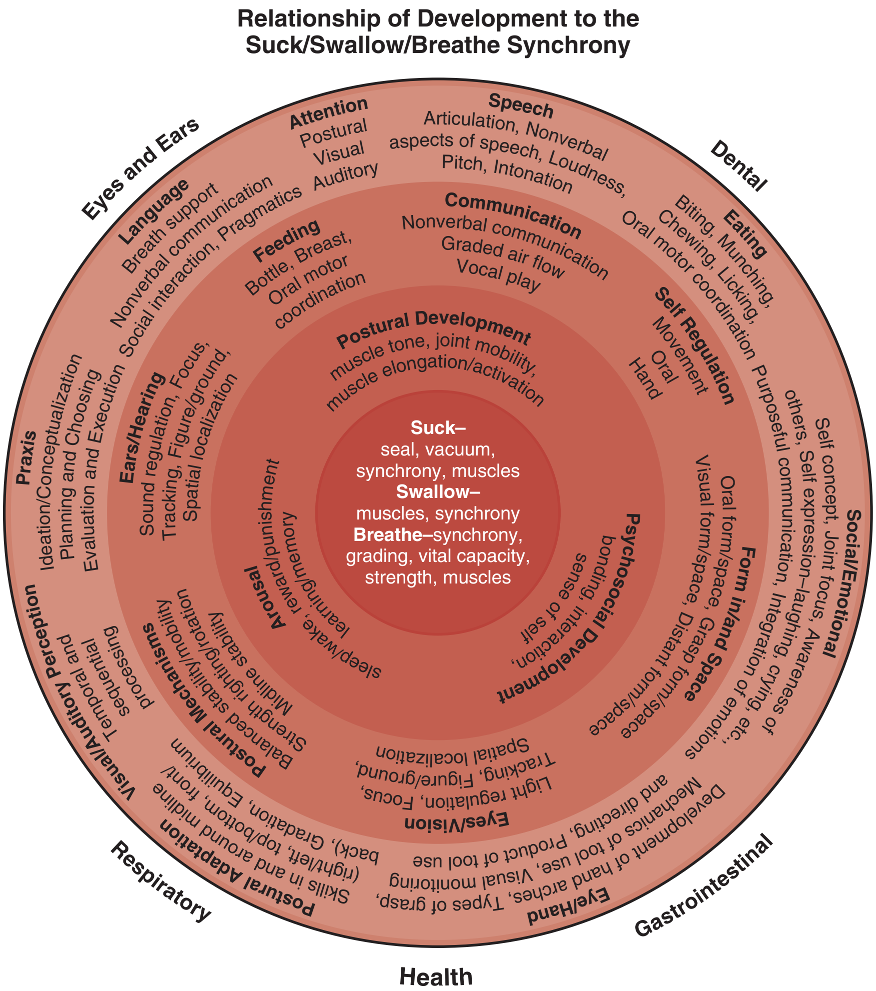

FIGURE 18-15 The Suck/Swallow/Breathe Model. *From:* MORE: Integrating the Mouth with Sensory and Postural Functions *by Oetter, Richter, & Frick (1993).*

Program Description

Originally M.O.R.E. was the name applied to therapeutic principles used to guide the grading of oral motor activities to address deficits in SSB. Each letter in the acronym reflects an area addressed in therapy: M for motor, O for oral, R for respiratory, and E for eyes (i.e., visual). We now refer to these therapeutic principles as the suck/swallow/breathe synchrony, although M.O.R.E. is still widely used.

Research and clinical observations of both typical and atypical SSB function have given rise to discreet strategies to include in intervention. These strategies are based on the following principles:

- Sucking requires the ability to create an oral seal and vacuum to activate the muscle synergies for use in supporting development.
- Control progresses from proximal to distal and from center ring on the model to the outer rings (Fig. 18-15).
- During a therapy activity, children seek oral input and demonstrate improved skill in area(s) in the outer rings. Children will need to return periodically to the SSB strategies (center) to support and maintain their activity in the outer rings. This means that quality and endurance in performance increases during a single session, and, through time, quality and endurance will improve with less intensity and frequency of return to center.

- Manual intervention may be necessary to release fixed muscles and activate stability or mobility in the jaw, tongue, cheeks, lips, neck, shoulder girdle, and diaphragm.
- SSB strategies should be integrated with functional outcomes such as eating, self-regulation, exploration, facial expression, and vocalization (refer to outer rings).
- Sucking, biting, and chewing should also be addressed to activate facial musculature and promote self-regulation through tongue, jaw, and cheek proprioception.
- Respiration is automatic but can also be controlled. It is easy to change, but changes require repetitive, functional use to maintain. The objective is to ensure that the lungs and ribcage are capable of three-dimensional expansion and the diaphragm is able to grade breath appropriate to the demands of a given task (Massery, 2012).

Typical activities to engage sucking or chewing might include:

- Use of various-sized straws, tubing, bottle nipples, or sports bottles (Fig. 18-16).
- Suck or explore objects of different sizes, shapes, tastes, or textures (e.g., red hots, sweet tarts, lemon drops, sour drinks, and carbonation).
- Promote bite or crunch with things such as pretzels, ice chips, or popcorn.
- Bite or tug opportunities that can engage the jaw and neck musculature (e.g., licorice, tubing, oral chewies, jerky, or fruit rollups).
- Gum (fresh or stale) can be offered for resistance. Note that regular (i.e., with sugar) gum offers initial resistance, then softens, allowing the muscles to activate initially. Sugar-free gum works in the reverse; it is initially soft with added resistance as chewing continues.

FIGURE 18-16 Blowing bubbles through a long straw. *Photo courtesy of Shay McAtee.*

Typical intervention strategies to support optimal respiratory function (and therefore posture) might include:

- Blowing or inhaling—straws, tubing, novelty blow toys, or bubbles
- Vocalizing through sound play—humming, animal sounds
- Manual techniques to release fixed muscles of the jaw, tongue, cheeks, trunk, shoulder girdle, and diaphragm

SSB concepts and strategies are meant to be incorporated into the child's therapy program along with many other techniques for improving sensory and motor processing and development. Oral motor activity can be incorporated into meals and snacks, as well as play with the toys and items that children and adults frequently put in the mouth for oral motor self-regulation.

Relationship to Sensory Integration and Occupation

Children with SSB difficulties often have sensory integrative, particularly postural, dysfunction. The intervention principles are therefore often embedded in sensory integrative therapy. Working on SSB synchrony involves child-directed oral exploration of taste, texture, and temperature; shapes; and play with breath (whistles and blowing). Supplementary hands-on facilitation of respiratory functions related to depth, rate, and use of breath (postural musculature) may also be used. Additional therapy targets may include oral motor or eating skills, self-regulation, and articulation.

Expected Benefits

The benefits of using SSB strategies are based on the authors' longstanding experience. Rigorous research to test the effects of SSB strategies is needed to validate clinical reports.

SSB synergies support regulation, increase or maintain alertness, focus attention, support posture, enhance communication, perform skilled movement, and promote stability to enable "power" tasks (Frick, Frick, Oetter, & Richter, 1996). Therefore, some benefits of SSB activities include:

- Resistive sucking can improve visual focus for close work, and may also be organizing; strengthening the musculature improves eating, speech production (articulation), and facial expression.
- Chewing can increase alertness and attention to a task (Allen & Smith, 2012), head and neck flexor strength and core activation, and shoulder and pelvic stability for distal control (i.e., for hand function, climbing, kicking a soccer ball, etc.).
- Ability to change depth and rate of breath according to the task; graded breathing supports typical sleep patterns, physical activity, verbal and nonverbal communication, alertness, self-regulation, and attention.
- Sucking and blowing can support visual tracking and accommodation, improve binocular focus at varying focal lengths, activate facial musculature for articulation and emotional expression, increase core muscle strength for posture, and so on (Kolar et al., 2012; Massery, 2012).
- Suck, blow, bite, crunch, munch, and chew facilitate better control and function of the extraocular muscles and the muscles of the inner ear; these muscles are striated and therefore can be treated using the same principles of muscle development as used throughout the body.

Target Populations

SSB strategies are a normal part of daily life, and most of us use some variation of them to support a range of functional tasks (see Fig. 18-17; Frick et al., 1996). In addition, children and adults who have difficulty with SSB function, commonly those with developmental, sensory integrative, musculoskeletal, or frank neurological dysfunction, can benefit from this intervention.

Training Recommended or Required

Importantly, because oral motor and respiratory functions depend on cranial nerve function, knowledge of cranial nerve structure, related pathways, and integration with other areas of the CNS is critical to understanding the complex interactions that affect sensorimotor development and SI processing (Moore, 1990; Oetter, Richter, & Frick, 1993; Saladin, 2018).

Although no formal training is required for using the M.O.R.E. program and SSB synchrony strategies, therapists may need continuing education in SSB to develop an understanding of the intervention principles and skills to target and implement effective intervention. The book *MORE: Integrating the Mouth with Sensory and Postural Functions* (Oetter, Richter, & Frick, 1993) and *MORE: The DVD* (Oetter & Richter, 2004) provide extensive suggestions for identifying and ameliorating SSB dysfunction. These materials may be found at https://www.allmusic.com/artist/pileated-press-mn0003010174. Whistles and blow toys used to promote graded breathing can be acquired from www.sensorytools.net and other pediatric therapy suppliers. Information on courses may be found at www.eileenrichter.com and www.patriciaoetter.com.

CASE STUDY ▪ ELISHA

Elisha is a girl who is 6 years and 9 months old. We chose this case because the presenting issues are familiar to many occupational therapists and also because intervention using activities to promote SSB synchrony resulted in decreased sensory defensiveness, increased language, improved praxis, and increased occupational performance, especially in play.

Elisha's mom reported that Elisha was delivered at term following an unremarkable pregnancy. Early on, Elisha had difficulty attaching to and remaining attached to the breast, and that difficulty continued until she weaned

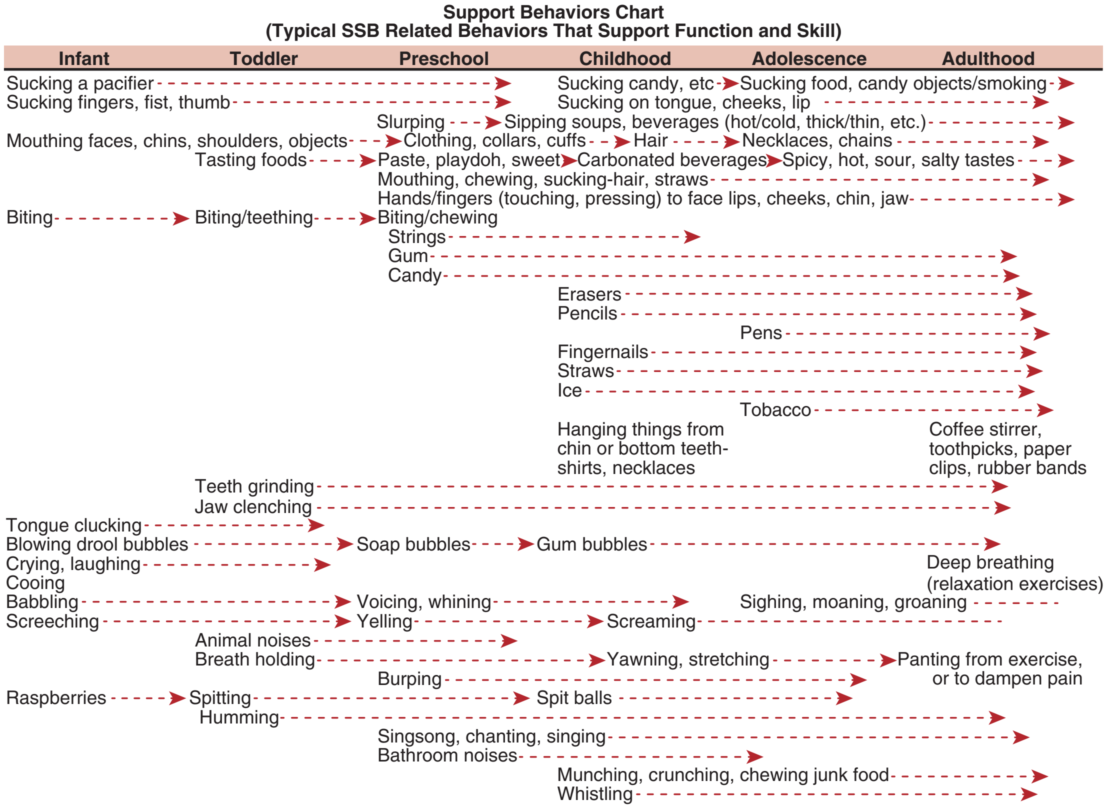

FIGURE 18-17 Relationships among SSB functions in typical development. *From:* Out of the Mouths of Babes: Discovering the Developmental Significance of the Mouth *by Frick, Frick, Oetter, & Richter (1996). Pileated Press, LLC, Stillwater, MN.*

herself at 8 months and switched to a sippee cup. Once Elisha got into preschool and first grade, her teachers had concerns about language organization and speech. In addition, her motor skills were a bit awkward, and often she avoided the slide, climber, and swings on the playground. For Elisha, peer interaction was minimal.

Primary concerns that were uncovered include severe sensory defensiveness as well as a very high palate and very weak and arrhythmic suck. In addition, Elisha had a poor SSB synchrony and synergy. Her jaw was retracted and fixed, limiting excursion. Elisha had cheek retraction, resulting in an ever-present "smile" and inability to get lip closure to suck the contents off a spoon or to produce labial sounds (p,b,m). Elisha's food preferences were limited.

Elisha had low normal muscle tone. Additional postural concerns ranged from poor head and neck alignment (head forward and extended), to a fixed shoulder girdle that did not support hand development, to a rib cage that was high and tight, resulting in a rapid and shallow breathing pattern regardless of activity level, and a "fixed" trunk and diaphragm that were noted during gross motor activity and activity requiring skilled eye-hand coordination. Elisha had issues with binocular vision, making it difficult to view objects both near and far.

Regarding oral, fine, and gross motor activities, Elisha avoided all activities requiring problem-solving or praxis, head down or backward space, as well as swings or climbers of any kind.

Through an integrated occupational therapy program, we worked with Elisha in an intensive block: 2½-hour sessions during 5 consecutive days, employing a multipronged approach. Although SSB synchrony strategies were an important part of intervention, we also employed Wilbarger's Therapressure™ Protocol (every 2 hours), Therapeutic Listening®, and the ATP (see more description in this chapter). We chose to address the sensory defensiveness and SSB issues first, believing that lessening these problems would enable other therapy to have a more profound effect on Elisha's postural and practic development.

We implemented SSB activities to address core tone; breathing patterns and breath support for all activities; sucking, mouth, and eating issues; and diaphragm, rib, and shoulder girdle fixation. We also included activities more traditionally associated with sensory integrative intervention and other programs as noted. We describe our SSB strategies and SI activities by day.

Day One

- SSB activities to release the connective tissue around the jaw, neck, shoulder girdle, spine, diaphragm, and pelvic girdle; for example, bite and tug to elongate the neck and align the jaw, suck a sour or cold, thick smoothie to generate more organized tongue movement and upper trunk co-contraction, or blow darts to increase the depth and rate options for breath.

Day Two

- Continued connective tissue releases occur.
- SSB activities with emphasis on bite or tug, resistive suck, and soft chew; for example, bite or tug on chewy tubes, exercise tubing, or a "chewy necklace," and sucking thickened, intense-tasting liquids through a straw (thickened with applesauce, banana, or yogurt). All activities were chosen with the intensity of taste she preferred; for example, lemon, cranberry, and grapefruit gums or juices.
- The last portion of Day Two, following SSB activities, Elisha chose climbing the ramp to jump into the cloud swing (six layers of 5' x 9' sheets of four-way stretch Lycra). In the Lycra, she wanted to be intensely swung and bounced. As she repeated this activity many times, she began laughing and talking about the experience.

Following the Day Two intervention, Elisha's parents reported that she chatted all the way home and asked many questions about what she was seeing out the window. These were new behaviors as Elisha never talked in the car, and neither Mom nor Grandma could remember Elisha ever asking a question. They also reported a noticeable improvement in her articulation and organization of language.

Day Three

- We introduced the ATP (see Section 5 of this chapter).
- Sensory diet continued and expanded to include:
  - Suck, blow, and bite (e.g., with, for example, whistles, bubbles, and straws).
  - During snack time, we provided foods that had intense flavor and various textures and degrees of resistance.
- Mouth and cheek massages to help with the tightness in her jaw, cheeks, and lips.

Days Four and Five

- Elisha created her own activities that challenged posture and praxis. She incorporated activities that involved SSB (e.g., whistles, kazoos, and singing).

Elisha's comment following the Day Four intervention said it all. With a full, natural smile, she said, "The fog has lifted!" Her dad remarked that he had never seen her really play with such joy.

With phone consultation weekly and then monthly, Elisha's family implemented a daily home program involving SSB oral and breath activities and cheek massages, as well as Therapeutic Listening® and the Astronaut Training Program. We also coached her school speech and language pathologist (SLP). Elisha engaged in two 2-day "tune ups" at 3 and 6 months, which completed her occupational therapy.

Summary and Conclusions

The eight programs described in this chapter represent a sample of the breadth of tools used by occupational therapy practitioners to supplement intervention based on the principles of SI theory. All are complementary to SI theory; some are more closely allied with it than others. This chapter does not represent an endorsement of any of these programs. Our intent is to alert readers to some of the available programs, provide information for learning more about them, and instill in readers an interest in pursuing empirical research in these areas.

Where Can I Find More?

Dimitrijević, L., Aleksandrović, M., Madić, D., Okičić, T., Radovanović, D., & Daly, D. (2012). The effect of aquatic intervention on the gross motor function and aquatic skills in children with cerebral palsy. *Journal of Human Kinetics, 32,* 167–174. doi:10.2478/v10078-012-0033-5

Gjesing, G. (1997, autumn). Water activities: Purposeful therapy for children with special educational needs. *Newsletter of the National Association of Paediatric Occupational Therapists.* London, UK: Oxford Information.

Gjesing, G. (1998, spring). Water activities as an OT intervention for children (and adults) with physical and/or mental disabilities. *Newsletter of the Aquatic Therapy Network for Occupational Therapists.* Available from A.T.N., 2424 Hirst Terrace, Haverton, PA 19083-1417.

Gjesing, G. (2013). *Reflections on promoting activity, participation, playfulness and sensory integration through water-based intervention—a contribution to water-based intervention from an occupational therapist perspective* (2nd ed.). Unpublished paper, see https://www.gjesing-haderslev.dk

Lepore, M., Gayle, G. W., & Stevens, S. F. (2007). *Adapted aquatics programming: A professional guide* (2nd ed.). Champaign, IL: Human Kinetics.

Salzman, A., & Tvrdy, J. (2009). *Aquatic sensory integration for the paediatric therapist.* Retrieved from www.aquaticnet.com

Shaw, S., & D'Angour, A. (2001). *The art of swimming.* London, UK: Ashgrove Publishing/Hollydata Publishers LTD.

References

The Wilbarger Approach to Treating Sensory Defensiveness

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles, CA: Western Psychological Services.

Bhopti, A., & Brown, T. (2013). Examining the Wilbargers' deep pressure and proprioceptive technique for treating children with sensory defensiveness using a multiple-single-case study approach. *Journal of Occupational Therapy, Schools, & Early Intervention, 6*(2), 108–130.

Chapparo, C., & Mora, L. (2011). Use of a sensory protocol by parents of children with intellectual disability and sensory defensiveness to achieve functional and behavioural goals: A randomised controlled study. *Australian Occupational Therapy Journal, 58*(Suppl. 1), 51–104.

Davis, T. N., Durand, S., & Chan, J. M. (2011). The effects of a brushing procedure on stereotypical behavior. *Research in Autism Spectrum Disorders, 5,* 1053–1058. doi:10.1016/j.rasd.2010.11.011

Deer, T. R., & Leong, M. S. (Eds.). (2012). *Comprehensive treatment of chronic pain by medical, interventional, and integrative approaches: Textbook on patient management.* New York, NY: Springer.

Dunn, W. (2014). *Sensory Profile-2 manual.* San Antonio, TX: (Pearson) Psychological Corporation.

Emami, S.F., Pourbakht, A., Daneshi, A., Sheykholeslami, K., Emamjome, H., & Kamali, M. (2013). Sound sensitivity of the saccule for low frequencies in healthy adults. *IRSN Otolaryngology,* http://dx.doi.org/10.1155/2013/429680

Field, T. (2010). Touch for socio-emotional and physical well-being: A review. *Developmental Review, 30*(4), 367–383. doi:10.1016/j.dr.2011.01.001

Field, T. (2011). Massage therapy: A review of recent research. In M. Hertenstein & S. Weiss (Eds.), *The handbook of touch: Neuroscience, behavioral, and health perspectives* (pp. 455–468). New York, NY: Springer.

Frick, S. M., & Young, S. R. (2009). *Listening with the whole body: Clinical concepts and treatment guides for Therapeutic Listening®.* Madison, WI: Vital Links.

Hertenstein, M., & Weiss, S. (Eds.). (2011). *The handbook of touch: Neuroscience, behavioral, and health perspectives.* New York, NY: Springer.

Kimball, J. G., Lynch, K. M., Stewart, K. C., Williams, N. E., Thomas, M. A., & Atwood, K. D. (2007). Using salivary cortisol to measure the effects of a Wilbarger protocol-based procedure on sympathetic arousal: A pilot study. *American Journal of Occupational Therapy, 61*(4), 406–413.

Kinnealey, M., Oliver, B., & Wilbarger, P. (1995). A phenomenological study of sensory defensiveness in adults. *American Journal of Occupational Therapy, 49*(5), 444–451.

LeDoux, J. (1996). *The emotional brain: The mysterious underpinnings of emotional life.* New York, NY: Simon & Schuster.

LeDoux, J. (2014). Low roads and higher order thoughts in emotion. *Cortex: A journal devoted to* *the study of the nervous system & behavior, 59,* 214–215. doi:10.1016/j.cortex.2014.06.008

Moore, K. M., & Henry, A. D. (2002). Treatment of adult psychiatric patients using the Wilbarger protocol. *Occupational Therapy in Mental Health, 18*(1), 43–63.

Oetter, P., Richter, E., & Frick, S. (1995). *MORE: Integrating the mouth with sensory and postural functions* (2nd ed.). Hugo, MN: PDP Press.

Ornstien, R., & Sobel, D. (1987). *The healing brain: Breakthrough discoveries about how the brain keeps us healthy.* New York, NY: Simon & Schuster.

Parham, L. D., Cohn, E., Spitzer, S., Koomar, J., Miller, L., Burke, J., . . . Summers, C. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61*(2), 216–227.

Parham, L. D., Ecker, C., Miller-Kuhaneck, H., Henry, D. A., & Glennon, T. J. (2007). *Sensory Processing Measure (SPM): Manual.* Los Angeles, CA: Western Psychological Services.

Pert, C. B. (1997). *Molecules of emotion.* New York, NY: Scribner.

Pfeiffer, B., & Kinnealey, M. (2003). Treatment of sensory defensiveness in adults. *Occupational Therapy International, 10*(3), 175–184.

Pribram, C. (1991). *Brain and perception: Holonomy and structure in figural processing.* Hillsdale, NJ: Erlbaum.

Reynolds, S., & Lane, S. J. (2008). Diagnostic validity of sensory over-responsivity: A review of the literature and case reports. *Journal of Autism & Developmental Disorders, 38*(3), 516–529. doi:10.1007/s10803-007-0418-9

Rolls, E. T. (2014). *Emotion and decision-making explained.* Oxford, UK: Oxford University Press.

Sterba, J. A., Safar-Riessen, D., & DeForest, M. (2004). Effect of aquatic therapy on gross motor function measure in children with cerebral palsy. *Developmental Medicine and Child Neurology, 46* (s99), 47–48.

Stratton, J., & Gailfus, D. (1998). A new approach to substance abuse treatment. Adolescents and adults with ADHD. *Journal of Substance Abuse Treatment, 15*(2), 89–94.

Sudore, K. (2001). Tactile defensiveness and the Wilbarger brushing protocol in system management. Unpublished master's thesis. D'Youville College, Buffalo, New York.

Upledger, J. E., & Vredevoogd, J. (1983). *Craniosacral therapy.* Seattle, WA: Eastland Press.

Weeks, S., Boshoff, K., & Stewart, H. (2012). Systematic review of the effectiveness of the Wilbarger protocol with children. *Pediatric Health, Medicine & Therapeutics, 3*, 379–389.

Weiss-Salinas, D., & Williams, N. (2001). Insights in practice. Sensory defensiveness: A theory of its effect on breastfeeding. *Journal of Human Lactation, 17*(2), 145–151.

Wilbarger, P. (1993). *Sensory defensiveness.* Videotape. Hugo, MN: PDP.

Wilbarger, P., & Wilbarger, J. (1991). *Sensory defensiveness in children aged 2-12: An intervention guide for parents and other caregivers.* Denver, CO: Avanti Educational Programs.

Williams, M. S., & Shellenberger, S. (1994). *"How does your engine run?": A leader's guide to the Alert Program for self-regulation.* Albuquerque, NM: TherapyWorks.

Wink, S., McKeown, L., & Casey, J. (2017). Parents' perspectives of using a therapeutic listening program with their children with sensory processing difficulties: A qualitative study. *Journal of Occupational Therapy, Schools, & Early Intervention*, doi: 10.1080/19411243.2017.1304839

Withersty, D. J., Stout, J., Mogge, N. L., Nesland, A., & Allen, D. (2005, January). Evaluating the use of the Wilbarger intervention with schizophrenic patients: A pilot study. *Psychiatry, 2*(1), 47–49.

The Alert Program® for Self-Regulation

American Occupational Therapy Association. (2014). Occupational therapy practice framework: Domain and process (3rd ed.). *American Journal of Occupational Therapy, 68,* S1–S48.

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles, CA: Western Psychological Services.

Barnes, K. J., Vogel, K. A., Beck, A. J., Schoenfeld, H. B., & Owen, S. V. (2008). Self-regulation strategies of children with emotional disturbance. *Physical & Occupational Therapy in Pediatrics, 28*(4), 369–387.

Baumeister, R. F., & Vohs, K. D. (Eds.). (2011). *Handbook of self-regulation: Research, theory, and applications* (2nd ed.). New York, NY: Guilford Press.

Bertrand, J. (2009). Interventions for children with fetal alcohol spectrum disorders (FASDs): Overview of findings for five innovative research projects. *Research in Developmental Disabilities, 30,* 986–1006.

Chiodo, P. G. (2010). *Outcomes on attention with an implementation of the Alert Program® in a school-based setting.* Unpublished Evidence-Based Occupational Therapy Scholars Capstone, Chatham University. Pittsburgh, PA.

Clark, M. N., Pritchett, M. D., & Vandiver, A. L. (2011). *The effects of the Alert Program® on communication and interaction skills of adults with severe and persistent mental illness in a community mental health setting.* Unpublished master's thesis, Brenau University, Gainesville, Georgia.

Feldman, J. S. (2012, August 13). Treating pre-adolescents with anxiety disorders: Using cognitive-behavioral and sensory-integrative approaches for self-regulation. *ADVANCE for Occupational Therapists, 28*(17).

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth, A. J. (Eds.). (2012). *Principles of neural science* (5th ed.). New York, NY: The McGraw-Hill Companies.

Mac Cobb, S., Fitzgerald, B., & Lanigan-O'Keefe, C. (2014). The Alert Program for self-management of behavior in second level schools: Results of phase 1 of a pilot study. *Emotional and Behavioural Difficulties, 19*(4), 410–425. doi:10.1080/13632752.2014.903593

Mac Cobb, S., Fitzgerald, B., Lanigan-O'Keefe, C., Irwin, N., & Mellerick, N. (2014). Students with social, emotional, and behavioral difficulties: The Alert Program trial in post-primary schools. *Journal of Occupational Therapy, Schools, & Early Intervention, 7*(2), 106–119. doi:10.1080/19411243.2014.930606

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly, 28*(2), 314–324. doi:10.1016/j.ecresq.2012.07.008

McEwen, M. (2009). Tracking success. Unpublished manuscript. Albuquerque, NM: TherapyWorks, Inc.

Mercer, C. D., & Snell, M. E. (1977). *Learning theory research in mental retardation: Implications for teaching.* Columbus, OH: Merrill.

Nash, K., Stevens, S., Greenbaum, R., Weiner, J., Koren, G., & Rovet, J. (2015). Improving executive functioning in children with fetal alcohol spectrum disorders. *Child Neuropsychology, 21,* 191–209.

Schoonover, J. (2002, September 16). Teaching social skills. In Y. Swinth & B. Hanft (Eds.), School-based practice: Moving beyond 1:1 service delivery. *OT Practice,* 18–19.

Shanker, S. (2012). *Calm, alert, and learning: Classroom strategies for self-regulation.* Ontario, Canada: Pearson Canada, Inc.

Wells, A. M., Chasnsoff, I. J., Schmidt, C. A., Telford, E., & Schwartz, L. D. (2012). Neurocognitive habilitation therapy for children with fetal alcohol spectrum disorders: An adaptation of the Alert Program®. *American Journal of Occupational Therapy, 66,* 24–34.

Wilbarger, P. (1984). Planning a "sensory diet": Application of sensory processing theory during the first year of life. *Zero to Three, 5,* 7–12.

Williams, M. S., & Shellenberger, S. (1992). *An introduction to "How Does Your Engine Run?®" The Alert Program® for self-regulation* [Booklet]. Albuquerque, NM: TherapyWorks, Inc.

Williams, M. S., & Shellenberger, S. (1996). *"How Does Your Engine Run?®" A leader's guide to the Alert Program® for self-regulation.* Albuquerque, NM: TherapyWorks, Inc.

Aquatic Therapy

Dellaratta, C. (2002). *Effects of a group aquatic therapy program on gross motor development, water orientation and swimming skills in children with hypotonia.* Hamden, CT: Quinnipiac University.

Epps, H., Ginnelly, L., Utley, M., Southwood, T., Gallivan, S., Sculpher, M., & Woo, P. (2005). Is hydrotherapy cost-effective? A randomized controlled trial of combined hydrotherapy programmes compared with physiotherapy land techniques in children with juvenile idiopathic arthritis. *Health Technology Assessment, 9,* 1–76. DOI: 10.3310/hta9390

Getz, M., Hutzler, Y., & Vermeer, A. (2006). Effect of aquatic interventions in children with neuromotor impairments: A systematic review of the literature. *Clinical Rehabilitation, 20*(11), 927–936.

Halliwick Association of Swimming Therapy National Education Committee. (2010). *Halliwick swimming for disabled people* (3rd ed.). London, UK: Black.

Maynard, T. L. (2004). Evidence in practice: Water walking and strengthening for improving gait function for an adult with cerebral palsy. *Journal of Aquatic Physical Therapy, 12*(1), 24–32.

Vonder Hulls, D. S., Walker, L. K., & Powell, J. M. (2006). Clinicians' perceptions of the benefits of aquatic therapy for young children with autism: A preliminary study. *Physical & Occupational Therapy in Pediatrics, 26*(1-2), 13–22.

Yilmaz, I., Yanardag, M., Birkan, B., & Bumin, G. (2004). Effect of swimming training on physical fitness and water orientation in autism. *Pediatric International, 46*(5), 624–626.

Interactive Metronome®

Bartscherer, M. L., & Dole, R. L. (2005). Interactive Metronome® training for a 9-year-old boy with attention and motor coordination difficulties. *Physiotherapy Theory and Practice, 21*(4), 257–269.

Bear, M. F., Conners, B. W., & Paradiso, M. A. (2015). *Neuroscience: Exploring the brain.* Baltimore, MD: Lippincott, Williams and Wilkins.

Beebe, B., Jaffe, J., Markese, S., Buck, K., Chen, H., Cohen, P., . . . Feldstein, S. (2010). The origins of 12-month attachment: A microanalysis of 4-month mother-infant interaction. *Attachment & Human Development, 12*(1), 3–141.

Buhusi, C., & Meck, W. (2005). What makes us tick? Functional and neural mechanisms of interval timing. *Nature Reviews: Neuroscience, 6,* 755–765.

Cermak, S. A., & Larkin, D. (Eds.). (2002). *Developmental coordination disorder.* Albany, NY: Delmar/Thompson Learning.

Cosper, S. M., Lee, G. P., Peters, S. B., & Bishop, E. (2009). Interactive Metronome® training in children with attention deficit and developmental coordination disorders. *International Journal of Rehabilitation Research, 32*(4), 331–336.

Doussard-Roosevelt, J. A., McClenny, B. D., & Porges, S. W. (2001). Neonatal cardiac vagal tone and school-age developmental outcome in very low birth weight infants. *Developmental Psychobiology, 38,* 56–66.

Feldman, R. (2005). Mother-infant synchrony and the development of moral orientation in childhood and adolescence: Direct and indirect mechanisms of developmental continuity. Paper presented in the biennial meeting of the Society for Research in Child Development, Atlanta, GA.

Feldman, R. (2006). From biological rhythms to social rhythms: Physiological precursors of mother-infant synchrony. *Developmental Psychology, 42*(1), 175–188.

Feldman, R. (2007). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry, 48,* 329–354.

Feldman, R., & Greenbaum, C. W. (1997). Affect regulation and synchrony in mother-infant play as precursors to the development of symbolic competence. *Infant Mental Health Journal, 18*(1), 4–23.

Feldman, R., Greenbaum, C. W., & Yirmiya, N. (1999). Mother-infant affect synchrony as an antecedent of the emergence of self-control. *Developmental Psychology, 35*(1), 223–231.

Interactive Metronome. (2007). *IM certification provider training manual.* Interactive Metronome®, Inc. Retrieved from www.interactivemetronome.com.

Johansson, A. M., Domellöf, E., & Rönnqvist, L. (2012). Short- and long-term effects of synchronized metronome training in children with hemiplegic cerebral palsy: A two case study. *Developmental Neurorehabilitation, 15*(2), 160–169. doi:10.3109/17518423.2011.635608

Lewis, P. A., & Miall, R. C. (2006). Remembering the time: A continuous clock. *Trends in Cognitive Sciences, 10*(9), 401–406.

Lewis, P. A., & Walsh, V. (2005). Time perception: Components of the brain's clock. *Current Biology, 24,* 389–391.

Libkuman, T. M., Otani, H. O., & Steger, N. (2002). Training in timing improves accuracy in golf. *Journal of General Psychology, 129*(1), 77–96.

McGrew, K. S. (2013). *The science behind Interactive Metronome®: An integration of brain clock, temporal processing.* Brain Network and Neurocognitive Research and Theory Institute for Applied Psychometrics (IAP). A MindHub™ Pub: #2 3-4-13 v1.1.

Mirmiran, M., & Lunshof, S. (1996). Perinatal development of human circadian rhythms. *Progress in Brain Research, 111,* 217–226.

Papoušek, M. (2008). Disorders of behavioral and emotional regulation: Clinical evidence for a new diagnostic concept. In M. Papoušek, M. Schieche, & H. Wurmser (Eds.), *Disorders of behavioral and emotional regulation in the first years of life: Early risks and intervention in the developing parent-infant relationship* (pp. 53–84). Washington, DC: Zero to Three.

Porges, S. (2009). Reciprocal influences between the body and brain in the perception and expression of affect: A polyvagal perspective. In D. Fosha, D. J. Siegel, & M. F. Solomon (Eds.), *The healing power of emotion: Affective neuroscience, development & clinical practice* (pp. 27–54). New York, NY: Norton & Company.

Sabado, J. J., & Fuller, D. R. (2008). A preliminary study of the effects of Interactive Metronome® training on the language skills of an adolescent female with a language learning disorder. *Contemporary Issues in Communication Science and Disorders, 35,* 65–71.

Schore, A. N. (1996). The experience-dependent maturation of a regulatory system in the orbital frontal cortex and the origin of developmental psychopathology. *Development and Psychopathology, 8,* 59–87.

Schore, A. N. (1997). Early organization of the non-linear right brain. *Development and Psychopathology, 9,* 595–631.

Shaffer, R. J., Jacokes, L. E., Cassily, J. F., Greenspan, S. I., Tuchman, R. F., & Stemmer Jr., P. J. (2001). Effect of Interactive Metronome® training on children with ADHD. *American Journal of Occupational Therapy, 55,* 155–162.

Shumway-Cook, A., & Woollacott, M. (2007). *Motor control: Translating research into clinical practice.* Philadelphia, PA: Lippincott, Williams & Wilkins.

Sommer, M., & Rönnqvist, L. (2009). Improved motor-timing: Effects of synchronized metronome training on golfshot accuracy. *Journal of Sports Sciences & Medicine (Free electronic journal), 8*(4), 648–656.

Stern, D. N. (1984). Affect attunement. *Frontiers of Infant Psychiatry, 2,* 3–14.

Taub, G. E., & Lazarus, P. J. (2013). The effects of training in timing and rhythm on reading achievement. *Contemporary Issues in Education Research (CIER), 5*(4), 343–350.

Tierney, A. T., & Kraus, N. (2013). The ability to tap to a beat relates to cognitive, linguistic, and perceptual skills. *Brain and Language, 124*(3), 225–231. doi:10.1016/j.bandl.2012.12.01

Tronick, E. (2007). *The neurobehavioral and social-emotional development of infants and children.* New York, NY: W.W. Norton & Company.

Astronaut Training

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests manual.* Los Angeles, CA: Western Psychological Services.

Braswell, J., & Rine, R. (2006). Evidence that vestibular hypofunction affects reading acuity in children. *International Journal of Pediatric Otorhinolaryngology, 70*(11), 1957–1965.

Casselbrant, M., Villardo, R., & Mandel, E. (2008). Balance and otitis media with effusion. *International Journal of Audiology, 47*(9), 584–589.

Cronin, G., & Rine, R. (2010). Pediatric vestibular disorders: Recognition, evaluation, and treatment. *Quarterly Newsletter of the Vestibular Disorders Association, 27*(3), 1–7.

Goldberg, J., Wilson, V., Cullen, K., Angelaki, D., Broussard, D., Buttner-Ennever, J., . . . Minor, L. (2012). *The vestibular system: A sixth sense.* Oxford, UK: Oxford University Press, Inc.

Jeffery, N., & Spoor, F. (2004). Prenatal growth and development of the modern human labyrinth. *Journal of Anatomy, 204,* 71–92.

Kawar, M. (2005). A sensory integration context for vision. In M. Gentile (Ed.), *Functional visual behavior in children: An occupational therapy guide to evaluation and treatment options* (2nd ed., pp. 87–144). Bethesda, MD: AOTA.

Kawar, M., & Frick, S. (2005). *Astronaut training: A sound activated vestibular-visual protocol for moving, looking, and listening*. Madison, WI: Vital Links.

Peterson, M. L., Christou, E., & Rosengren, K. S. (2006). Children achieve adult-like sensory integration during stance at 12-years-old. *Gait and Posture, 23*(4), 455–463.

Rine, R. M. (2009). Growing evidence for balance and vestibular problems in children. *Audiological Medicine, 7,* 138–142.

Rine, R. M., Rubish, K., & Feeney, C. (1998). Measurement of sensory system effectiveness and maturational changes in postural control in young children. *Pediatric Physical Therapy, 10,* 16–22.

Schaaf, R. C., & Lane, S. J. (2009). Neuroscience foundations of vestibular, proprioceptive, and tactile sensory strategies. *OT Practice, 12,* CE 1–7.

Thaut, M. (2007). *Rhythm, music, and the brain: Scientific foundations and clinical applications.* New York, NY: Routledge.

Weiss, A., & Phillips, J. (2006). Congenital and compensated vestibular dysfunction in childhood: An overlooked entity. *Journal of Child Neurology, 21*(7), 572–579.

Infinity Walk

Sunbeck, D. (1996). *Infinity Walk: Preparing your mind to learn!* Torrance, CA: Jalmar Press.

Sunbeck, D. (2002). *The complete Infinity Walk, book 1: The physical self.* Rochester, NY: The Leonard Foundation Press.

Sunbeck, D. (2013). *The Infinity Walk method: A developmentally progressive and integrative systems approach to clinical treatment.* Retrieved from www.infinitywalk.org

Therapeutic Listening®

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Bazyk, S., Cimino, J., Hayers, K., Goodman, G., & Farrell, P. (2010). The use of therapeutic listening with preschoolers with developmental disabilities: A look at the outcomes. *Journal of Occupational Therapy, Schools, & Early Intervention, 3*(2), 124–138.

Bengtsson, S. L., Ullen, F., Ehrsson, H. H., Hashimoto, T., Kito, T., Naito, E., . . . Sadato, N. (2009). Listening to rhythms activates motor and premotor cortices. *Cortex, 45,* 62–71.

Frick, S. M., & Hacker, C. (2001). *Listening with the whole body.* Madison, WI: Vital Links.

Frick, S. M., & Lawton-Shirley, N. (1994). Auditory integrative training from a sensory integrative perspective. *Sensory Integration Special Interest Section Newsletter, 17,* 1–3.

Frick, S. M., & Young, S. R. (2012). *Listening with the whole body* (2nd ed.). Madison, WI: Vital Links.

Hall, L., & Case-Smith, J. (2007). The effect of sound-based intervention on children with sensory processing disorders and visual-motor delays. *American Journal of Occupational Therapy, 61,* 209–215.

Siddle, D. (1983). *Orienting and habituation: Perspectives in human research.* New York, NY: Wiley.

Thaut, M. H., & Abiru, M. (2010). Rhythmic auditory stimulation in rehabilitation of movement disorders: A review of current research. *Music Perception, 27*(4), 263–269.

Thaut, M. H., Kenyon, G. P., Schauer, M. L., & McIntosh, G. C. (1999).). The connection between rhythmicity and brain function: Implications for therapy of movement disorders. *Engineering in Medicine and Biology Magazine, 18,* 101–108.

Thaut, M. H., McIntosh, G. C., Prassas, S. G., & Rice, R. R. (1992). Effect of auditory rhythmic cueing on normal gait and gait in stroke, cerebellar disorder, and transverse myelitis. In M. Woollacott & F. Horak (Eds.), *Posture and gait: Control mechanisms* (pp. 437–440). Eugene, OR: University of Oregon.

Tomatis, A. (1996). *The ear and language.* Ontario, Canada: Moulin Publishing.

Wilbarger, J., & Frick, S. (2011, June 30). *Clinical conversation: Sensory modulation.* Madison, WI: Vital Links.

Wink, S., McKeown, L., & Casey, J. (2017). Parents' perspectives of using a therapeutic listening program with their children with sensory processing difficulties: A qualitative study. *Journal of Occupational Therapy, Schools, & Early Intervention,* doi:10.1080/19411243.2017.1304839

Suck, Swallow, Breathe

Allen, A., & Smith, A. (2012, July). *Effects of chewing gum and time-on-task on alertness and attention.* doi:10.1179/1476830512Y.0000000009

Ayres, A. J. (1973). An interpretation of the role of the brain stem in intersensory integration. In A.

Henderson & J. Coryell (Ed.), *The body senses and perceptual deficit* (pp. 81–94). Boston, MA: Sargent College of Allied Health Professions.

Barlow, S. M. (2009). Central pattern generation involved in oral and respiratory control for feeding in the term infant. *Current Opinion in Otolaryngology Head Neck Surgery, 17*(3), 187–193.

Brownlee, S., & Watson, T. (1997). The senses. *U.S. News and World Report, 122*(1), 50–59.

Frick, S., Frick, R., Oetter, P., & Richter, E. (1996). *Out of the mouths of babes: The developmental significance of the mouth.* Stillwater, MN: Pileated Press, LLC.

Gentilucci, M., & Campione, G. C. (2011). *Do postures of distal effectors affect the control of actions of other distal effectors? Evidence for a system of interactions between hand and mouth.* Retrieved from PLOS One https://www.ncbi.nlm.nih.gov/pubmed/21625428

Kalnins, I., & Bruner, J. (1973). The coordination of visual observation and instrumental behavior in early infancy. *Perception, 2*(3), 307–314.

Kolar, P., Sulc, J., Kyncl, M., Sanda, J., Cakrt, O., Andel, R., . . . Kobesova, A. (2012). Postural function of the diaphragm in persons with and without low back pain. *Journal of Orthopaedic & Sports Physical Therapy, 42*(4), 352–362.

Massery, M. (2012). Multisystem clinical implications of impaired breathing mechanics and postural control. In D. Frownfelter & E. Dean (Eds.), *Cardiovascular and pulmonary physical therapy: Evidence to practice* (5th ed., pp. 633–653). St. Louis, MO: Elsevier-Mosby.

Montegue, A. (1986). *Touching: The human significance of the skin* (3rd ed.). New York, NY: Harper and Row.

Moore, J. (1990). Highlights of nervous system development and function. In E. Gilfoyle, A. P. Grady, & J. Moore, *Children adapt* (2nd ed., pp. 35–85). Thorofare, NJ: Slack Inc.

Oetter, P., & Richter, E. (2004). *The M.O.R.E. DVD: Integrating the Mouth with Sensory and Postural Functions*. Stillwater, MN: Pileated Press.

Oetter, P., Richter, E. W., & Frick, S. (1993). *MORE: Integrating the mouth with sensory and postural functions.* Stillwater, MN: Pileated Press, LTD.

Pickler, R. H., Frankel, H., Walsh, K. M., & Thompson, N. M. (1996). Effects of non-nutritive sucking on behavioral organization and feeding performance in preterm infants. *Nursing Research*, *45,* 132–135.

Rochat, P. (1993). Hand-mouth coordination in the newborn: Morphology, determinates and early development of a basic act. In G. Savelsbergh & G. Savelsbergh (Eds.), *The development of coordination in infancy*. Amsterdam: Elsevier Science Publishers, pp. 265–288.

Saladin, K. (2018). *Anatomy and physiology: The unity of form and function* (3rd ed.). New York, NY: McGraw-Hill.

CHAPTER 19

Application of Sensory Integration with Specific Populations

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By autistic standards, the "normal" brain is easily distractible, is obsessively social, and suffers from a deficit of attention to detail and routine. Thus people on the spectrum experience the neurotypical world as relentlessly unpredictable and chaotic, perpetually turned up too loud, and full of people who have little respect for personal space.

—Steve Silberman, *NeuroTribes: The Legacy of Autism and the Future of Neurodiversity* (p. 471)

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe sensory-based concerns for infants who have been in neonatal intensive care units.
- ✔ Describe common patterns of sensory integrative dysfunction in individuals with attention deficit-hyperactivity disorder (ADHD) and autism spectrum disorder (ASD).
- ✔ Apply principles of sensory integration (SI) for evaluating and intervening with children with ADHD and ASD, and discuss research supporting SI approaches with these populations.
- ✔ Apply principles of SI for evaluating and intervening with children with disorders of trauma and attachment, and discuss research supporting sensory-based approaches with this population.
- ✔ Apply principles of SI for evaluating and intervening with adults with and without mental health disorders, and discuss research supporting SI approaches in the context of occupational therapy with adults.
- ✔ Describe common patterns of SI dysfunction occurring in adults with disorders of mental health, and in adults with no other identifiable diagnosis.

Introduction

Sensory integration (SI) theory, evaluation, and intervention principles can be applied to children and adults with a wide variety of diagnostic conditions. Application across a wide variety of populations makes perfect sense because SI deficits often coexist with, or are characteristic of, many different conditions, and they can occur throughout the life span. For example, atypicalities in sensory processing are cited as diagnostic criteria for autism spectrum disorder (ASD; American Psychiatric Association [APA], 2013a). An abundance of literature has been published during the past 10 years describing the types of sensory processing and integration deficits typically seen in individuals who fall within various diagnostic groups. For example, Wells, Chasnoff, Schmidt, Telford, and Schwartz (2012) described the types of SI challenges commonly seen in children with fetal alcohol syndrome; Mouchet-Mages, Canceil, Willard, and Krebs (2007) described sensory differences seen in patients with schizophrenia; and Parush, Sohmer, Steinberg, and Kaitz (2007) described sensory modulation concerns of boys with **attention deficit-hyperactivity disorder (ADHD).** Here we describe the application of SI constructs across commonly served diagnostic groups.

This chapter is divided into six sections by population or condition. The rationale for using SI, and information describing how SI as a frame of reference can be applied for guiding evaluation and intervention, is included for the following populations:

- Section 1: Sensory Integration Applications with Infants in Neonatal Intensive Care and Early Intervention (by Rosemarie Bigsby)
- Section 2: Sensory Integration Approaches with Individuals with Attention Deficit-Hyperactivity Disorder (by Shelley Mulligan)
- Section 3: Applying Sensory Integration Principles for Children with Autism Spectrum Disorder (by Teal W. Benevides, Rachel Dumont, & Roseann C. Schaaf)
- Section 4: Sensory Integration and Children with Disorders of Trauma and Attachment (by JoAnn Kennedy)
- Section 5: Sensory Integration Applications with Adults (by Beth Pfeiffer)
- Section 6: Sensory Integration Approaches with Adults with Mental Health Disorders (by Tina Champagne & Beth Pfeiffer)

Research explaining the relationship between sensory processing patterns and each condition is highlighted, along with research describing the potential benefits of using SI strategies with each population. Ideas for evaluation and intervention using an SI approach are shared, and case studies are presented to illustrate how SI has been practically applied in the context of occupational therapy services. This chapter was written by multiple authors to take advantage of the expertise of those with experience working within each of the populations addressed.

Section 1: Sensory Integration Applications with Infants in Neonatal Intensive Care and Early Intervention

Rosemarie Bigsby, ScD, OTR/L, FAOTA

Background and Rationale for Applying Sensory Integration

Human behavior is inextricably tied to the senses. At every age and stage of development, our thoughts, emotions, and actions are shaped by our experiences. Sensation is registered and processed, amplified, attenuated, or ignored, constructing our experience of the world. Recognizing the impact of sensory experiences on the developing brain, clinicians aim to enhance infant development by intervening when infants present with atypical responses to sensory experiences. Furthermore, it is imperative that interventions are respectful of the family's primary role in the lives of their children, and decisions regarding intervention practices are made in consideration of the best available evidence of the potential effects of specific interventions (Dunst, Bruder, & Espe-Shervindt, 2014).

Infants and young children sometimes present with atypical responses to sensory experiences within the context of daily routines, limiting active participation in many of the necessary developmental tasks and skills of infancy. These include exhibiting optimal levels of arousal and affect for given contexts, developing positive interactions with their caregivers, and progressing within and across all areas of development (Cohn & Tronick, 1987). For decades, therapists have adapted the vocabulary, definitions, and interventions characteristic of SI treatment for applications in their work with infants and toddlers and their families (Williamson & Anzalone, 2001). Yet the question of whether it is appropriate to apply an approach that was conceived for school-aged children (Ayres, 1972) to a much younger population has not been adequately addressed. The existing research on the efficacy of SI theory and treatment has predominantly focused on school-aged children, and the evidence that is available has been criticized for methodological limitations such as small sample sizes, lack of controls and of blinded assessment, and absence of fidelity to the components of intervention that are considered essential to SI treatment (Parham et al., 2011). A review of research examining the effectiveness of SI intervention appears in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research). Some recommendations that can be made based on previous research that are useful for guiding further research with children of all ages including infants are as follows: (1) examining the effectiveness of child (infant)-directed activity (i.e., modifying treatment according to individual preferences and responses of the child); (2) comparing the effects of sensory-based interventions experienced in the home setting with parents guiding the intervention versus therapist-directed sessions in community-based or clinic settings; and (3) examination of the relations among physiological measures (autonomic stability [e.g., vagal tone, galvanic skin response] and regulation of arousal, attention, and behavior in infancy including preterm infants).

Sensory Integration in Early Infancy and Associated Occupation-Based Challenges

This section provides an overview of how sensory experiences may impact the developing fetus through infancy. The human fetus encounters multiple, simultaneous sensory inputs throughout gestation, and the intrauterine environment has a buffering effect, limiting the intensity of exposure to these multisensory experiences (Lickliter, 2011). In contrast, preterm infants born as early as 23 weeks post-conception, and who are cared for in medical care environments such as neonatal intensive care units (NICU), experience sensory stimuli often in ways that bear little resemblance to what would be experienced in the natural, intrauterine environment. For example, the timing, intensity, types, and duration of exposure may differ significantly and have little relationship to the infants' level of maturation, sensory needs, or individual tolerances. Depending on the timing of exposure, sensory experiences in the NICU have the potential to undermine development of the infants' ability to regulate states of arousal, to attend to and process sensory information, and, ultimately, to develop age-appropriate social-emotional responses (Weisman, Magori-Cohen, Louzoun, Eidelman, & Feldman, 2011).

Although the senses function in concert from early infancy, individual sensory systems become functional in the fetus in the following invariant order: tactile, vestibular, auditory, and finally visual. Because of this sequence, the sensory modalities have "markedly different developmental histories at the time of birth" (Lickliter, 2011, p. 594). Depending on the timing of introduction of stimuli from one sensory system, sensory responsiveness in another sensory modality may be inhibited or enhanced. In the case of preterm infants, the intensity and type of sensory stimuli within the NICU environment, as well as the timing of and context for stimulation, are dramatically different from the experience of infants born at term, and these experiences could have implications for later sensory functioning. For example, Rahkonen and colleagues (2015) conducted a prospective study of 44 infants born at fewer than 28 weeks gestation, and assessed at 2 years corrected age, using the Infant/Toddler SP (Dunn, 2002) as well as cognitive scales. They demonstrated that half the sample had at least one atypical area of sensory processing, with low registration being the most common atypical sensory processing pattern. Chorna and colleagues (2014) prospectively studied 72 infants born weighing at least 1,500 grams using the Test of Sensory Function in Infants (DeGangi & Greenspan, 1989); the researchers demonstrated that at 4 to 12 months corrected age, 82% of the infants had at least one atypical score. The lower the gestational age at birth, the greater the association with atypical responses to deep pressure and vestibular activity. Although these studies have small sample sizes, their effect sizes are sufficiently large to suggest the need for further exploration of these relationships and for consideration of approaches to early infant intervention that could reduce the risk of sensory issues in the low birthweight preterm population.

The infant's ability to transition from one state of arousal to another is one of the most reliable expressions of an infant's tolerance for a particular sensory experience. Holditch-Davis and Thoman (1987) and Weisman and colleagues (2011) proposed that transitions between different sleep states among preterm infants may be predictive of cognitive, neurobehavioral, and emotional developmental outcomes. There is evidence that slow wave (deep sleep) in particular is characterized by an increased balance between excitatory and inhibitory signaling and of protein synthesis, suggesting that deep sleep may have a singular role in brain plasticity (Aton, 2013). Infants may show that an experience is tolerated by sustaining a particular state of arousal, whether a particular sleep state or a particular level and quality of alertness. Infants also may demonstrate tolerance by transitioning gradually to a new state of arousal, such as awakening slowly from a sleep state. However, sensory stimuli that are perceived as stressful may contribute to increasing arousal toward an irritable state or may produce inhibition—a pulling down toward a drowsier state to effectively "tune out" continued interaction. These behavioral responses may represent an adaptive, protective response on the part of the infant, whose behavioral expression of his or her unique threshold for stimulation may not be easily recognized by the caregiver. A recent meta-analysis of studies incorporating sensory modulation abilities of preterm infants demonstrated relationships between these sensory modulation challenges and length of stay in the NICU, degree of white matter injury, and later cognitive and behavioral outcomes (Bröring, Oostrom, Lafeber, Jansma, & Oosterlaan, 2017).

Evaluation and Intervention in the NICU

Both the physical environment for NICUs and care practices have been studied for their impact on developmental outcomes, and there is little doubt that sensory factors involved within each contribute to the quality of life experienced by NICU survivors. Two overarching principles of NICU care that have achieved broad acceptance are: (1) providing care that is modified to the individual sensory thresholds of the infant, offering not only protection from unnecessary stress but also enhancement of the infant's unique capacities for physiological and behavioral organization, and (2) integrating the infant's family into all aspects of care, thus supporting the role of the family as the constant in the infant's life. These principles are grounded in **transactional developmental theory** (Sameroff & Chandler, 1975), a systems theory that acknowledges the impact of three main components: the infant, the caregiver, and the environment. This systems theory emphasizes how each of the three components interacts and affects one another, as well as how the transactions among these components contribute to developmental outcome. Transactional developmental theory fits into the broader framework of dynamic systems theory in which characteristics of the individual, in concert with affordances within the environment and timing of sensory experiences and activities, have the potential to move the individual forward in development (Smith & Thelen, 2003). **Synactive theory** (Als, 1982) is a dynamic systems theory that is specific to NICU care. In synactive theory, the self-regulatory capacities of the infant represent the maturation of and interplay between the infant's autonomic, state, motor, and attentional or interactive subsystems. Inherent in the application of synactive theory to developmental support in the NICU is the importance of: (1) assessing the infant's individual capacity for self-regulation within the context of NICU care, and (2) working with caregivers to modify aspects of care on an ongoing basis in order to achieve a better fit between the infant's tolerances or needs and the care that is provided.

These child-directed approaches involve modifying care practices and the environment according to an infant's individual thresholds for managing sensory input and capacity for self-regulation. This same principle is essential to SI treatment when it is practiced optimally—providing the "just right" challenge and constantly assessing child responses in order to adapt the sensory experiences and demands for achieving an adaptive response from the child. Also, these systems approaches underscore the importance of parent and caregiver participation, which has been shown to be very effective in the context of sensory-based interventions (Case-Smith, Weaver, & Fristad, 2014; Dunst et al., 2014). These principles of NICU care, with a particular focus on providing guidance for enhancing parent sensitivity to infant behavior, parent participation in care, and collaboration with NICU therapists, have been shown to produce positive outcomes in infant brain structure and function, pain reduction and reduced medical morbidity, and weight gain (Als et al., 2004; Lester et al., 2014). Yet, wide variations in care practices and standards of care continue to exist among different NICUs across the country and internationally. Subsequently, there are potentially large numbers of infants vulnerable to atypical or suboptimal sensory experiences who may be at risk for developing sensory-related dysfunction as a consequence of NICU care.

Neuroprotective care is another recommended standard care practice for NICU providers. This approach emphasizes stress and pain reduction, position and handling techniques, partnering with families, and the regulation of sleep and states of arousal in order to promote a more stable, well-regulated infant (Altimier, Kenner, & Damus, 2015). Neuroprotective care can be practiced within the dynamic systems approaches discussed previously. From birth, the NICU patient is assessed in terms of arousal and spontaneous activity and exposure to stress. Necessary yet stressful interventions may be modified by providing positive touch and soothing containment, such as skin-to-skin holding, hand swaddling or facilitated tucking, sucking on a pacifier sweetened with mother's expressed breast milk or sucrose, or by implementing a combination of these interventions (Liaw et al., 2013). These sensory techniques may enhance infant tolerance for painful procedures, and they may be helpful for preserving sleep. Unnecessary stressors can be largely reduced by modifying

PRACTICE WISDOM: BUILDING A FOUNDATION FOR POSITIVE SENSORY EXPERIENCES THROUGHOUT INFANCY

Educate families about evidence-based approaches to supporting early sensory experience and demonstrate sensitivity to infant behavioral communication.

- Attention to infant behavior and arousal
  - Babies communicate availability for interaction or stress through their posture, movement, facial expressions, and level of arousal
  - There is an expected range of infant crying, sleep, and arousal patterns (https://www.cdph.ca.gov/Programs/CFH/DWICSN/CDPH%20Document%20Library/Families/FeedingMyBaby/970027-Getting-To-Know.pdf)
- Supports to enhance early caregiving interactions
  - "Asking permission"—approaching the baby with adult presence first, then introducing soft voice and resting hands
  - Postural containment (swaddling, holding close) to soothe and organize
  - Skin-to-skin holding (kangaroo mother care) throughout early infancy
  - Nuzzling at the breast as preparation for breastfeeding (http://www.breastcrawl.org/video.shtml)
  - Slow position changes to minimize startles
  - Swaddled bathing
  - Use of a wrap or baby carrier to keep baby close (in vertical position on chest for safety)
- Modulated sensory experiences—following the baby's lead
  - Soft talking and "Parentese" to capture the baby's auditory attention
  - Slow movement in baby's view to entice the baby to visually attend
  - Watching and waiting—pausing and observing the baby's response to talk, touch, and movement-play before continuing
  - Floor-play and contingent responses—allowing the baby some space to explore on his or her own, and "being there" to respond when the baby communicates his or her needs and wants
  - "Taking turns"—building reciprocity in vocal and motor responses
  - Joint attention—looking where the baby looks or points, and picking up on the baby's interest with descriptive talk and demonstration
  - Gradual introduction of new sensory experiences—massage, swing, wind and rain, new sounds, and talking through the experience
  - Respecting the baby's need to pull back from something that may seem overwhelming
  - Demonstrating delight when the baby has a positive response to something new

the NICU environment, such as providing single family room care whenever possible, targeting sources of excessive noise, and using adjustable, cycled lighting to help establish diurnal rhythms.

Sensory-based, environmental interventions are incorporated into care in many NICU settings. However, to achieve widespread improvements in developmental outcomes and to optimize long-term effects, particularly with extremely low birthweight (ELBW; fewer than 1,000 grams) infants, NICU practitioners also need to consider the conditions under which these interventions are being implemented, including consideration of the timing of intervention and parental participation. The importance of utilizing appropriate sensory-based input, provided by parents with considerations given to timing, was emphasized in a recent follow-up study by Feldman and colleagues (2014) (see Here's the Evidence box). On the strength of these findings, as well as other long-term follow-up studies and meta-analyses (Boundy et al., 2016; Charpak et al., 2017; Conde-Agudelo & Diaz-Rossello, 2016), **skin-to-skin care** (kangaroo mother care) is now recommended for universal use for low birthweight infants. The data supporting infant massage in the NICU is not as strong. A recent meta-analysis points to many potential benefits of this sensory-based intervention for preterm infants, but also concedes that more study is needed before it can be recommended without reservation (Niemi, 2017).

It is important to acknowledge that the responses of NICU patients to their care are particularly nuanced and individualized. Preterm infants are not only immature but may differ

HERE'S THE EVIDENCE

Feldman and colleagues (2014) conducted a 10-year follow-up of a randomized controlled study of very low birth weight (fewer than 1,500 grams) preterm infants, matched on gestational age at birth, birth weight, illness severity, sex, socio-economic status, and demographics, with 73 infants in each group. The intervention group received skin-to-skin holding during a 2-week period while in the NICU. During the 10-year period, improved respiratory sinus arrhythmia (vagal tone), infant-caregiver interaction, and performance scores related to language, cognitive, motor, and externalizing behaviors have persisted among the children in the intervention group. Feldman and colleagues (2014) attribute these lasting effects not only to the specific benefits of skin-to-skin holding as an early intervention but also to the conditions under which it was administered and the positive effect on infant-caregiver relationships. The authors concluded that when parents learn to be sensitive to their infant's behavioral and physiological cues very early on, this relationship provides a foundation for communicative synchrony going forward. These researchers presented a systems model that is consistent with dynamic systems theories, including synactive theory, and, it could be argued, aspects of SI intervention. Important concepts of their model included: (1) specificity—targeting of specific processes shown to be linked with the expected improvements; (2) sensitive periods—even small inputs or minor changes have the potential to have a major effect when delivered during critical periods; and (3) incorporation of individually stable components—introducing an intervention at a time when it is possible to build on the natural stability of other functions.

Feldman, R., Rosenthal, Z., & Eidelman, A. (2014). Maternal-preterm skin-to-skin contact enhances child physiologic organization and cognitive control across the first 10 years of life. *Biological Psychiatry, 75,* 1, 56–64.

dramatically in their ability to register sensations and to process them. By virtue of their immature neurological pathways, thresholds for tolerating sensory experiences vary significantly among low birth weight preterm infants. Although they are often exquisitely sensitive to sensory stimuli, they also are not mature enough to produce an organized response that is easily recognized by caregivers. This may leave infants susceptible to painful, uncomfortable, or excessive sensory input, which has the potential to negatively affect brain development (Vinall & Grunau, 2014). On the other hand, **protective factors** in the life of the infant have the potential to mediate those negative influences. Parent involvement in NICU care, caregiver sensitivity to the infant's behavioral and physiological responses to care, and sensory experiences that are appropriately timed and modulated to the infants' tolerances have been demonstrated to mediate those negative influences, and to result in improved behavioral, developmental, and even neurological outcomes (Lester et al., 2016; Milgrom et al., 2010; Wolke, Jaekel, Hall, & Baumann, 2013).

Evaluation and Intervention in Early Intervention Programs

It is well established that early and intensive intervention for young children (before 3 years of age, and the earlier the better) with neurodevelopmental problems, such as sensory processing disorders and autism, results in significant improvements in adaptive functioning and promotes development across multiple domains (Bailey et al., 2005; Dawson & Bernier, 2013). Therefore, the identification of sensory processing challenges and initiation of therapeutic services as early as possible is very important. The emphasis on early diagnosis and intervention for infants and toddlers with neurodevelopmental problems that may result from prematurity, or because of conditions such as autism, has resulted in more young children being served by Part C of the Individuals with Disabilities Education Act (IDEA; U.S. Department of Education, Office of Special Education and Rehabilitative Services, Office of Special Education Programs, 2014). This program provides federal funding and mandates interdisciplinary, family-centered early supports and services for children under 3 years of age who qualify for services, based on a developmental disability or risk for developmental problems.

In order to develop the most appropriate Individual Family Service Plan (IFSP) for infants receiving early intervention services, initial and ongoing assessment must include a semi-structured or structured parent interview and observation of infant behavior and developmental competencies within the infant's natural setting. When these observations take place during familiar daily routines such as playful interaction between parent and infant, feeding, dressing, and bathing, they provide a rich source of information for the early intervention therapist. These activities help the therapist and parents to collaborate in identifying infant thresholds for various sensory experiences, individual strengths, and potential concerns that may require further evaluation. The Bayley Scales of Infant and Toddler Development-III (Bayley, 2005) and the Mullen Scales of Early Learning (Mullen, 1995) are assessment tools for measuring overall development (motor, perceptual, communication, social-emotional, cognition, and behavior, in terms of both "expressive" and "receptive" abilities), which also provide some useful information about sensory processing abilities of young children. Administration of the Infant-Toddler Sensory Profile 2 (SP2; Dunn, 2014) or the Test of Sensory Function in Infants (DeGangi & Greenspan, 1989) provide more specific information regarding sensitivities and tolerance for various activities, interactions, and environmental stimuli specific to individual sensory systems (e.g., vestibular, tactile, auditory, visual, taste, and smell).

Dunn (2002, 2014) developed a theoretical model for describing the *sensory processing patterns* of young children to assist in identifying sensory processing difficulties. The patterns are conceptualized as resulting from interaction between neurological threshold and self-regulatory behaviors. Dunn described four patterns (see Chapter 6, Sensory Modulation Functions and Disorders), recognizing that children may exhibit a mixed sensory profile (i.e., exhibiting behaviors in more than one category). The first pattern, registration, is reflected by a combination of high neurological threshold and passive behavioral response. Dunn terms these children "bystanders," indicating that they tend to respond too slowly to sensory stimuli and miss more sensory information than do other children. They may appear uninterested; have low energy levels or low muscle tone; show decreased awareness of people, objects, or common dangers; or have a high tolerance to pain. "Seeking" is another pattern that reflects high neurological threshold, this time coupled with active self-regulation strategies. Children characterized as seekers look excessively for activities that provide them with specific types of sensory input (e.g., tactile, movement, visual, etc.). These children may be described by caregivers as overly active, impulsive, excitable, and sometimes disruptive. The third pattern, "sensitivity," characterizes children with low neurological thresholds and passive self-regulation strategies. These children are often "on alert," making them appear distractible and hyperactive. They may be described as being easily upset when they are overstimulated, may have a low tolerance to pain, may not want to be cuddled, and may be picky eaters. Finally, the "avoiding" pattern is characterized by low neurological thresholds coupled with active self-regulatory strategies. Children with this pattern are very sensitive to sensation and prefer order and sameness as a way to avoid unexpected sensations. Children who are "avoiders" tend to withdraw from situations they perceive as threatening. Infants and toddlers exhibiting any of the previously noted patterns may benefit from an individualized therapeutic approach to optimize their comfort and participation in age-appropriate developmental activities. Thus, family-centered, early supports and services administered through IDEA, Part C are typically provided in the home or within other natural contexts such as day-care settings.

Therapists collaborate with parents and caregivers to identify sensory-related challenges within these contexts and to develop strategies for modifying the daily environment and activities to optimize comfort and active participation for the infant or toddler. Everyday activities of infants and toddlers provide important sensory experiences that expand the child's understanding of the world. SI theory can be applied with infants and toddlers to help caregivers incorporate the appropriate types of activities into their daily routines and to modify such aspects as the timing and intensity of the activity to enhance development of sensory integrative functioning. Activities such as feeding; dressing and diaper changing; splashing in the water while bathing; exploring textured surfaces such as carpeting, grass, and sand; and swinging and climbing at the park can be modified, according to the infant or toddler's tolerance, to ensure they are pleasurable for both the child and the caregiver. Play experiences that provide an element of challenge to the child, while remaining pleasurable, lay the foundation for competence and confidence, as well as providing motivation for further exploration. Perhaps most importantly, activities that are perceived as pleasurable by both members of the interactive dyad support healthy social and emotional relationships between infants or toddlers and their caregivers. Through early intervention services that incorporate education, modeling, collaboration, and, most importantly, active problem-solving, parents and caregivers become more astute observers of their child's responses to various experiences and improve their ability to make their own modifications in sensory aspects of day-to-day activities (Dunst et al., 2014). These parent and caregiver competencies ensure an optimal environment for infants who might otherwise be at risk to explore and learn from the world around them.

CASE STUDY ▪ LILY

From her first days in the NICU, Lily, born at 26 weeks gestation, was described as "underaroused." As she matured, NICU staff frequently voiced concerns that she was "under-responsive." Her parents rejected that interpretation. They participated in neurobehavioral assessments with the occupational therapist and collaborated in developing the neuroprotective care plan posted at her bedside: offering containment, nested positioning (Fig. 19-1), and slow changes in position; holding her skin-to-skin for hours each day (Fig. 19-2); softly talking, reading, and singing to her; and allowing her to nuzzle at the breast, and offering breast or bottle only for as long as she was able to participate actively in feeding, requesting the remainder be fed by gavage. At 31 weeks corrected age, her father began gentle daily massage, modified according to her tolerances. She "slept through" many of her care times, sustaining quiet alertness only briefly before pulling down to a drowsy state, and some nurses were concerned that her "low-key" routine was keeping her too "sedate." However, both her parents and a strong primary nurse advocated for staying with the plan. They gradually introduced more challenging care routines, such as bathing (Figs. 19-3 and 19-4). By 38 weeks corrected age, she was able to sustain arousal for feeding and became more easily engaged in interaction, and at 39 weeks, still with short periods of visual alertness (Fig. 19-5), but with good weight gain, she was discharged home. Lily's mother stayed in contact with the NICU through a blog and by e-mail, and it soon became clear that Lily was blossoming at home. She began to have longer periods of alertness, became increasingly active and responsive, and her parents followed her lead, offering more opportunities for sensory exploration, according to her cues. By the end of her first year, she was on target developmentally, "babbling up a storm" and demonstrating "creativity" in her explorations (e.g., using whatever happened to be available

FIGURE 19-1 Lily responded well to resting hands at head and feet, for soothing, during care. She is under phototherapy, with eye protection, which makes her even more sensitive to caregiver touch. *Photo courtesy of Christina DiChiera.*

FIGURE 19-2 Lily and Mom began skin-to-skin holding as soon as Lily had stable ventilator settings. *Photo courtesy of Christina DiChiera.*

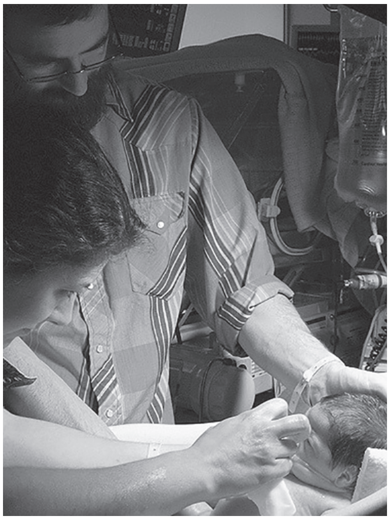

FIGURE 19-3 Lily's parents were active participants in her care and were delighted when she was able to tolerate a tub bath. *Photo courtesy of Christina DiChiera.*

FIGURE 19-5 At 38 weeks, Lily was still easily stressed by handling, but she tolerated vertical rocking to increase her alertness for the photo. *Photo courtesy of Christina DiChiera.*

FIGURE 19-4 Lily enjoys a warm cuddle with Mom while drying off after her bath. *Photo courtesy of Christina DiChiera.*

as steps to climb up and peek out the window). At age 6, Lily has emerged as a superstar—a bright, socially interactive, curious kindergartner, with neonatal follow-up records that show above-average cognitive, language, motor, and social-emotional scores.

Lily exemplifies the infant who might be described as "inhibited" or "avoiding" but who is actually signaling her high reactivity and her need for caregivers to accommodate her by modulating levels of stimulation. Her caregivers chose activities that were appropriate to her gestational age and stage of sensory development—focusing, during her earlier weeks in the NICU, on the tactile, vestibular, and auditory systems, which are better prepared to process input than the visual system. They were responsive to her behavioral communication and provided increasing challenges as she demonstrated readiness, motivation, and self-directed exploration. Most importantly, her care was predominantly provided by her parents, leading to continuity after discharge, timed to her readiness, and emphasized interactions that integrated the sensory experiences within an age-appropriate caregiving context rather than focusing on specific sensory interventions. This approach is similar to that recommended by Case-Smith and colleagues (2014)—focusing on sensory integrative experiences rather than on individual sensory-based interventions. Haith (1991) challenged his colleagues in psychology to move in this direction in their research on perceptual processes in infancy—away from a focus on individual inputs to a more integrated, dynamic systems approach that is client-centered and that involves contextual and environmental elements, caregiver involvement, and consideration of the infant's readiness and needs.

HERE'S THE POINT

- SI and other sensory-based interventions have important contributions to make in the care of infants in NICU settings, as well as in early intervention services.
- Interventions aim to accommodate the individual sensory thresholds of infants with sensory processing challenges to avoid unnecessary stress and enhance the infant's unique capacities for physiological and behavioral organization.
- Providing family-centered services within the infant's natural environment is essential when working with infants and toddlers to ensure that sensory aspects of the environment are integrated into developmental services, and to ensure that the role of the family as the constant in the infant's life is optimized.

Where Can I Find More?

Bröring, T., Oostrom, K. J., Lafeber, H. N., Jansma, E. P., & Oosterlaan, J. (2017). Sensory modulation in preterm children: Theoretical perspective and systematic review. *PLOS ONE, 12*(2). doi:10.1371/journal.pone.0170828

Charpak, N., Tessier, R., Ruiz, J. G., Hernandez, J. T., Uriza, F., Villegas, J., . . . Maldonado, D. (2017). Twenty-year follow-up of kangaroo mother care versus traditional care. *Pediatrics, 139,* 1, 1–10.

Conde-Agudelo, A., Diaz-Rossello, J. L. (2016). Kangaroo mother care to reduce morbidity and mortality in low birthweight infants. *Cochrane Database Systematic Reviews, Aug 23* (8), CD002771. doi:10.1002/1465858.CD002771.pub4

Niemi, A. (2017). Review of randomized controlled trials of massage in preterm infants. *Children, 4*(4), 21. doi:10.3390/children4040021

Section 2: Sensory Integration Approaches with Individuals with Attention Deficit-Hyperactivity Disorder

Shelley Mulligan, PhD, OTR/L, FAOTA

Background and Rationale for Applying Sensory Integration

ADHD is the most common neurobiological disorder that manifests in childhood, and it often continues into adolescence and adulthood (Wolraich et al., 2012). ADHD is placed within the section describing neurodevelopmental disorders in the *Diagnostic and Statistical Manual for Mental Disorders,* Fifth Edition (*DSM-5;* APA, 2013b), and it is characterized by persistent and maladaptive symptoms of inattention, hyperactivity, and impulsivity. The average age of onset is 7 years, and boys are four times more likely than girls to have the disorder. The prevalence of ADHD has steadily increased during the past 20 years, and it is now reported as affecting approximately 11% of children across the United States (APA, 2013b) and from 4% to 6% of adults. According to the *DSM-5,* ADHD

TABLE 19-1 Behaviors Associated with ADHD Symptoms

INATTENTIVE BEHAVIORS	HYPERACTIVE-IMPULSIVE BEHAVIORS
• Forgetfulness • Failing to give close attention to details • Making careless mistakes in schoolwork, work, or other activities • Overlooking or missing details • Difficulty sustaining attention in tasks or play activities • Appearing to not listen when spoken to directly (e.g., mind seems to wander) • Difficulty following through on instructions and with task completion • Poor organizational skills	• Fidgety • Trouble sitting still or staying seated • Feeling restless • Talking excessively • Difficulty waiting or taking turns

Adapted from the American Psychiatric Association. (2013a). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

includes three clinical presentations: combined, predominantly inattentive, and predominantly hyperactive-impulsive. Behaviors characterizing inattention and hyperactivity-impulsivity are listed in Table 19-1. The label of ADHD-combined is given to adults and children who exhibit symptoms from both the attention and hyperactive-impulsive categories. An ADHD diagnosis is made when several symptoms are present before 12 years of age, and inattentive or hyperactive-impulsive symptoms must be observed in two or more settings (e.g., home and school). There also must be clear evidence that symptoms interfere with, or reduce the quality of, the individual's social functioning, academic performance, or ability to perform the desired and necessary occupations (APA, 2013b).

It is important to keep in mind that normal child behavior often includes having a high activity level, being easily distracted, and acting impulsively. All children mature at different rates, and their personalities, sensory processing abilities and preferences, and energy levels are variable, which makes it challenging to discern true ADHD from normal behavior (Holmberg, Sundelin, & Hjern, 2013). Also complicating matters is that ADHD is often comorbid with motor, sensory, learning, mood, anxiety, and disruptive behavior disorders in children and adults.

Sensory Integration and Associated Occupation-Based Challenges

Kaplan and colleagues (2006) reported that as many as 80% of children with ADHD are at risk of having at least one other disorder, such as a reading disability, developmental coordination disorder (DCD), oppositional behavior disorder, or anxiety. Motor disorders have been reported in as many as 40% to 60% of individuals representing all three subtypes of ADHD, with slightly more representation in the combined clinical presentation (Egeland, Ueland, & Johansen, 2012; Piek & Dyck, 2004). Disorders of attention and learning have also been associated with sensory processing disorders or SI dysfunction (Dunn & Bennett, 2002; S. J. Lane, Reynolds, & Thacker, 2010; Mangeot et al., 2001; Mulligan, 1996; Pfeiffer, Daly, Nicholls, & Gullo, 2015). Children with ADHD have an increased risk of sensory modulation difficulties (sensory over-responsivity [SOR] or sensory under-responsivity [SUR]) as well as deficits in visual perception (Miller, Neilson, & Schoen, 2012; Yochman, Parush, & Ornoy, 2004). ADHD and SOR may also be linked with anxiety in this population (S. J. Lane et al., 2010; S. Reynolds & Lane, 2009). In addition, studies have shown that ADHD is associated with adverse reactions to tactile stimuli and motor planning problems (Parush, Sohmer, Steinberg, & Kaitz, 2007). Mulligan also demonstrated postural control and balance deficits, sensory-based dyspraxia, and visual-motor integration difficulties in this group of children (Mulligan, 1996). More recently, Pfeiffer, Daly, Nicholls, and Gullo (2015) found that children with ADHD were much more likely to exhibit challenges in all areas of sensory processing than those of neuro-typical children and to display problems with higher level functions believed to be dependent in part on efficient sensory processing, including social participation and motor planning. The close association between attention deficits and impairments

HERE'S THE EVIDENCE

Pfeiffer and colleagues (2014) collected data on sensory processing (Sensory Processing Measure–Home Form; Parham & Ecker, 2007) and child behavior (Conners Manual 3rd Edition–Parent Short Form; Conners, 2008) on 20 children with ADHD and 27 children with no diagnosis, from 5 to 10 years of age. Their goal was to investigate whether children with ADHD had more sensory processing concerns than did typical children, to characterize those concerns as they related to core features of ADHD, and to examine differences that might be linked with medication use. Using multivariate analysis and controlling for differences based on age, they determined that children with ADHD differed from typical children in sensory processing. Through follow-up using univariate analyses and adjusting for multiple comparisons, these investigators determined that children with ADHD had higher mean scores on all subscales of the SPM, with a small to medium effect size (η^2 ranging from 0.27 to 0.61). On further examination, they also determined that there was no difference within the group with ADHD for children taking or not taking medication. Not surprisingly, investigators also found that children with ADHD had higher mean scores for *Hyperactivity/Impulsivity* [$F(1,44) = 104.88$, $p < .001$] and *Inattention* [$F(1,44) = 99.90$, $p < .001$] subscales on the Conners; there were no differences between groups based on medication. Examining the correlation between the SPM and Conners subscales, investigators found moderate correlations between *Hyperactivity/Impulsivity* and *Social* ($r = 0.50$, $p < .05$) and *Planning and Ideas* ($r = 0.73$, $p < .01$) subscales of the SPM. No links between specific sensory systems and subscales on the Conners were found. These findings suggest that sensory processing concerns in children with ADHD are substantive, impacting occupational performance and engagement. Further research is needed to better understand the links between ADHD core symptoms and praxis concerns, and to further examine sensory-system-specific sensory processing.

Pfeiffer, B., Daly, B. P., Nicholls, E. G., & Gullo, D. F. (2014). Assessing sensory processing problems in children with and without attention deficit hyperactivity disorder. *Physical & Occupational Therapy in Pediatrics, 35*(July 2013), 1–12. doi:10.3109/01942638.2014.904471

with sensory, motor, and perceptual functions is further supported by the work of Gillberg (2003) and Hellgren and colleagues (1994). These investigators refer to this as a condition called DAMP, or deficits in attention, motor control, and perception. Therefore, it is not surprising that Ayres Sensory Integration® (ASI) and other sensory-based approaches have commonly been used by occupational therapists with this population.

Evaluation and Intervention

Comprehensive evaluations of children with ADHD using an SI approach include administration of the Sensory Integration and Praxis Test (SIPT; Ayres, 2005), a measure of sensory modulation such as the SP (Dunn, 2014), clinical observations, as well as gathering information through interviews and naturalistic observations when possible. Other assessments may help to explore the cognitive and **executive functions** that are characteristic of the disorder; for instance, the Brief Rating Inventory of Executive Functions (Giolo, Isquith, Guy, & Kenworthy, 2000), Dynamic Occupational Therapy Cognitive Assessment for Children (DOTCA-Ch; Katz, Parush, & Traub-Bar-Ilan, 2004), the Leiter-3 International Performance Scale–3rd edition (Roid, Miller, Pomplun, & Koch, 2004), the Executive Function Performance Test (Baum et al., 2008), the Stroop Color and Word Test (Golden & Freshwater, 2002), and the Test of Every Day Attention for Children (Manly, Robertson, Anderson, & Nimmo-Smith, 1998).

There is no question that sorting out the underlying cause of challenging behaviors associated with inattention, which may include SUR or SOR, is difficult; such challenging behaviors may be linked with the ADHD diagnosis, an underlying sensory processing disorder, or both. One of the best ways to deal with this dilemma is to carefully attend to the client's response to specific interventions and then adjust intervention to meet the individual's needs. For example, if a child starts a trial of stimulants for managing his or her ADHD symptoms, and then the child's sensory processing problems diminish significantly, using an SI approach may not be indicated.

Individuals with ADHD are typically treated with a **multi-modal,** multi-disciplinary approach. For example, interventions for children often include parental and child education about ADHD; school-based, educational interventions; specialized therapies, such as occupational therapy using an SI approach; and medication management for those choosing medication. In addition, many adults and older children benefit from psychotherapies, such as cognitive-behavioral therapy, and interventions to address daily life activities that may be disrupted, such as work, leisure, driving, or social relationships. Pharmacotherapy, however, remains the cornerstone for ADHD intervention for all age groups, with advances in long-lasting **stimulant medications** being the most common (DeSousa & Kalra, 2012). Research on treatment effectiveness has largely focused on comparing the relative gains in managing ADHD with medication versus the effects of behavior therapies alone. Studies comparing medication with non-pharmacological interventions have consistently shown stimulants to be superior to non-drug treatments, according to the American Academy of Pediatrics (2011) and DeSousa and Kalra (2012). However, the combination of medication and behavioral interventions is more beneficial than medication alone (Murray et al., 2008).

ASI is a useful treatment approach for children with ADHD if specific patterns of SI dysfunction have been identified. During intervention sessions, it is important to emphasize sensory activities that aim to regulate the child's level of arousal throughout the session as well as those aimed at addressing specific problems, such as dyspraxia or visual motor integration deficits. Treatment spaces may be better able to meet the child's needs if they are free from clutter to minimize distractions and the potential for the child to become overstimulated. Allowing the child to choose those activities that he or she enjoys is vital, as children with ADHD may only be able to attend to tasks well when they are invested in or interested in whatever they are doing. Recent reviews and studies of the effectiveness of ASI intervention with children with ASDs and other conditions have shown the intervention to be effective in occupational goal achievement and for improving SI functions (May-Benson & Koomar, 2010; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011). Miller, Coll, and Schoen (2007) found that in addition to being effective for goal achievement, SI intervention helped children improve more than control subjects on cognitive measures including attention.

In addition to ASI, sensory-based approaches have also been used with children with ADHD to assist in **behavior regulation** and to address more directly the undesirable behaviors associated with the disorder, such as hyperactivity and inattention. Other studies have used tools such as weighted vests for calming children and increasing attention and on-task behavior, although success has been mixed (Collins & Dworkin, 2011; Lin, Lee, Chang, & Hong, 2014; Olson & Moulton, 2004b; VandenBerg, 2001). Alternate classroom seating, such as move and sit cushions or therapy ball type seats, has also been used to enhance on-task behavior, reduce undesirable behavior, and improve handwriting in children with symptoms associated with ADHD (Fedewa & Erwin, 2011; Schilling, Washington, Billingsley, & Deitz, 2003). Other sensory-based programs such as the Alert Program (Williams & Shellenberger, 1996) may be useful in assisting children to maintain optimal levels of arousal (see Chapter 18, Complementary Programs for Intervention, for more detail). The **Zones of Regulation** (Kuyper, 2011) program also addresses behavior regulation, including the sensory needs of the child. This program provides a framework for educating children and adults about behavioral regulation, and it is geared toward helping students understand their emotions and gain skills in consciously regulating their actions, which, in turn, leads to increased control and problem-solving abilities. Students engage in learning activities designed to help them recognize states of arousal and emotion, called "zones," and learn how to use strategies or tools, including sensory tools, to stay in a zone or move from one zone to another. Students develop their own toolbox of methods to use to move between zones. For more information, see zonesofregulation.com. Although there are not any well-designed studies that evaluate its effectiveness, Wells, Chasnoff, Schmidt, Telford, and Schwartz (2012) conducted a randomized controlled study of a neurocognitive group therapy intervention that applied many aspects of the Alert and the Zone programs. These researchers used a sample of children with fetal alcohol syndrome who exhibited many ADHD symptoms, and they found that the intervention improved executive functioning and emotional problem-solving skills.

The Interactive Metronome, a unique approach that incorporates aspects of sensory processing, has often been used with children with ADHD (see Chapter 18, Complementary Programs for Intervention). This approach aims to increase attention span and the ability to focus for extended periods, while addressing some SI functions, such as motor planning and rhythmicity of movement. In a well-controlled study with boys with ADHD from 6 to 12 years of age, Shaffer and colleagues (2001) demonstrated that the intervention was effective for improving several variables, including attention, motor control, language processing, and reading, as well as for reducing aggressive behavior.

Sensory-based interventions are commonly combined with ASI in addressing concerns. For instance, Sahoo and Senapati (2014) examined functional skills in home and school, comparing the effects of combining ASI with a sensory diet using an outdoor playground to ASI alone. Results suggested that both groups made functional gains in performance areas at home and school as well as with life skills and social behaviors. After 2 months of treatment, those receiving the sensory diet in addition to SI treatment made significantly more gains than those receiving just the SI intervention. It was concluded that SI intervention along with a sensory diet provided in the context of outdoor play is effective for improving functional skills of children with ADHD.

When applying SI as a frame of reference for adults with attention disorders, sensory-based strategies and SI techniques are commonly used to modify tasks and environments, as opposed to more traditional, clinic-based, ASI intervention. For adults, instrumental activities of daily living, social participation, and work are the types of occupations that are most often impacted by symptoms of ADHD and, therefore, addressed by occupational therapists. Adults with ADHD, for example, have been shown to have lower rates of professional employment (Cermak & Maeir, 2011). Driving has also been an area that has received attention in the ADHD population, as teens and adults with ADHD have been shown to be at a higher risk for accidents and violations than control subjects (Molina et al., 2009). The **Dynamic Interactional Model of Cognition** (Toglia, 2011) is an example of an approach that has been used with adults with ADHD, and this model can easily be combined with SI techniques. In this model, cognitive function is viewed as an ongoing product of the dynamic interaction among the person, activity, and the environment (Toglia, 2011), and intervention can target any of these three components. Adults are taught to recognize the cognitive strategies they use to process information, to recognize their sensory preferences, how they typically process sensory information, and how the sensory features of environments and activities may support or hinder their functioning. Challenges with behavior regulation that relate to sensory sensitivities, or a need for increased sensory stimuli to maintain interest and focus during tasks, can be addressed through the use of sensory diets. Environmental modifications might include setting up quiet, uncluttered work areas to minimize visual and auditory stimulation and distractions. Simple highlighting or underlining of salient written instructions may assist in visually focusing, and tools such as day planners and personal electronic devices with reminders may assist with organization. The creation and following of predictable routines and adding structure to routines and tasks may assist with compensating for motor planning deficits and give the individual more control over the amount and type of sensory input that he or she experiences. As with children, sensory strategies, such as using a therapy ball as alternate seating, holding fidget toys, or using headphones to reduce sound, may be effective strategies for adults. Sensory diets that schedule time for physical activity, quiet time, or for engaging in whatever type of activities provide the individual with kinds of sensory input that help them self-regulate and perform can also be developed and implemented.

Important components of comprehensive occupational therapy programming for adults and children with ADHD to consider include: (1) education about the disorder and how one's symptoms influence everyday functioning; (2) techniques to remediate or compensate for executive function deficits and behavioral regulation; (3) techniques to remediate or compensate for coexisting conditions, such as motor coordination, memory, or SI problems, when they are identified and impact occupational performance; (4) environmental and task modifications, including sensory strategies to reduce distractions, increase structure and organization, and to enhance attention to tasks in home, work, or school settings; (5) behavioral interventions to learn, monitor, and reward identified desired behaviors, to reduce undesirable behavior, and to enhance motivation and task persistence; and (6) implementation of cognitive processing strategies to improve task performance and generalization of skills in the context of daily life. The application of SI theory and intervention techniques should be made with consideration of the client's own goals and priorities in mind and in concert with any other medical, pharmacological, psychological, or educational interventions that the client might be receiving.

CASE STUDY ▪ MORGAN

Morgan was referred by his pediatrician for occupational therapy at a private outpatient clinic specializing in SI to evaluate his sensorimotor abilities and fine and gross motor skills. Morgan had been diagnosed with ADHD, combined presentation, when he was 6 years of age and began to receive special education services when he was in the first grade. At the time he was referred for occupational therapy, he was in the third grade and receiving special education services to address difficulties with math, handwriting, and visual motor skills, as well as to assist in managing behavioral concerns in the classroom, including inattention and emotional outbursts. All his services were provided within the regular classroom, and he also received monthly classroom consult visits from the occupational therapist.

Morgan's pediatrician had suggested medication for managing Morgan's ADHD; however, his parents opted to try and deal with his behaviors using behavioral strategies. His parents had been through a parent training program to help them implement strategies to help control his behavior. His mother reported that he had difficulty making friends, was not involved in any extracurricular activities outside of school, and did not like school very much. Mom also indicated that Morgan cried frequently at home and was distressed by taking the bus to and from school. At home he liked to play computer games and build with Legos and required only minimal assistance to complete dressing, grooming, and bathing activities. Although she had set up a system of simple chores for him to do at home, Mom stated that Morgan required frequent reminders and assistance to complete them.

His occupational therapy evaluation included parent and child informal interviews, observations of and interactions with Morgan during several structured and unstructured gross and fine motor play activities, completion of the SP (Dunn, 1999), and administration of the SIPT (Ayres, 1989). Morgan scored within the average range on both of the SIPT tests examining non-motor visual space perception (Space Visualization, Figure-Ground). However, visual-spatial construction tasks involving motor planning were challenging for Morgan, and he scored below average on Constructional Praxis and Design Copying; he also had significant difficulty with Praxis on Verbal Command, whereas Postural Praxis and Oral Praxis scores were average. Morgan demonstrated some difficulties with tactile discrimination, and vestibular deficits were seen in low scores for Standing and Walking Balance and Post-Rotary Nystagmus. His score on Bilateral Motor Coordination was below average, whereas his score on the Motor Accuracy Test was average. These results suggested a sensory-based motor disorder, including both dyspraxia and bilateral integration and sequencing deficits. In consideration of the cluster analyses provided by his SIPT profile, Morgan was most closely likened to the visuo-somatodyspraxia grouping. Children likened to this group typically have problems with visual and space perception, most areas of praxis, tactile and proprioceptive processing, balance, and motor coordination.

The SP completed by his mother suggested that Morgan was overly sensitive to auditory stimulation and easily distracted by noise. There was some indication of mild tactile hypersensitivity, and Morgan was a picky eater. He was a child who sought out movement excessively with an increased activity level and inattention. He was described as an emotionally sensitive child with low tolerance for frustration and frequent emotional outbursts.

Clinical observations of Morgan indicated minimally lowered muscle tone globally and difficulty assuming anti-gravity postures, such as prone extension and supine flexion indicative of low tone and generalized muscle weakness. He walked and ran without difficulty, although his running speed was slow, and he did not demonstrate smooth reciprocal upper and lower extremity movements. Morgan experienced difficulty with coordination tasks, such as rapid alternating finger movements and jumping jacks, demonstrating a weakness with motor planning and sequencing.

In summary, these findings indicated that Morgan had SI deficits that were impacting his behavior at home and at school, his learning, and his development of fine and gross motor skills. More specifically, he demonstrated challenges with motor planning, balance, and bilateral motor coordination, which seemed to be related to poor tactile, proprioceptive, and vestibular processing. He also demonstrated some sensory modulation problems, including tactile and auditory over-responsivity, and difficulty modulating and processing vestibular and proprioceptive sensory input. Despite his difficulties, Morgan was a pleasant, well-mannered child who was interested in his environment and eager to please others.

Morgan received occupational therapy services on a weekly basis at school in the classroom. Strategies were implemented to help him compensate for his SOR to auditory and tactile stimuli, such as avoiding spaces that were crowded, loud, or unpredictable. He also began to use a Move and Sit cushion on his classroom chair, which gave him constant subtle movement, and this alternative seating significantly reduced his fidgetiness. Because children with motor planning problems typically experience difficulty in new situations and learning new skills, it was important that pre-teaching was conducted and more time and practice or repetition was allotted for Morgan to learn new skills. A variety of approaches, such as hands-on learning, demonstration, and talking through steps of tasks, were found to be helpful in facilitating Morgan's learning of new skills. The therapist also suggested that he be provided with ample opportunities to develop gross motor skills and move about during the day (receive proprioceptive and vestibular input) such as doing seat push-ups, using a rebounder in the classroom, and being able to stand rather than sit to complete some classroom activities.

In addition to school-based services, including occupational therapy, clinic-based occupational therapy using an SI approach was implemented once per week for 4 months. ASI was implemented to address Morgan's motor and postural responses, comfort with movement, muscle strength and balance, somatosensory processing, and motor planning and sequencing. At home, his therapist suggested that Morgan engage in play activities that help to develop his fine and gross motor skills, such as play with construction toys such as Legos and other building blocks, using clay and playdough, and engaging in any craft activities (cutting, gluing) that he enjoys. Morgan was encouraged to do functional tasks independently, such as dressing, brushing his hair and teeth, opening packages, and cutting meat, as well as complete simple chores. Gross motor play suggestions included riding his bike, playing ball games such as basketball and soccer, swimming, and playing on playground equipment such as climbing and swinging. Heavy work-type activities (pushing or pulling, carrying heavy objects, rough-house play, jumping on a trampoline, etc.) were encouraged at home and at school, and they were implemented frequently during his treatment sessions.

Morgan did well with intervention, and the sessions using SI were particularly effective for improving his motor planning skills and for improving his self-regulation of behavior. He continued to receive occupational therapy on a consult basis throughout the school year to address his behavior at school and to monitor the effectiveness of sensory strategies that were implemented to help him attend and focus.

HERE'S THE POINT

- ADHD is a complex condition, and many of the behavioral indicators of ADHD that are associated with poor behavior regulation mimic those seen in children with sensory modulation disorders.

- Comprehensive programs for those with ADHD are described as using an individually tailored, multi-modal intervention approach to meet the unique presentation of each client.
- For many adults and children with ADHD, occupational therapy services applying ASI or implementing sensory-based strategies to assist with behavior regulation as well as to address co-occurring SI dysfunction are often helpful.

Where Can I Find More?

Ratey, N. (2008). *The disorganized mind: Coaching your ADHD brain to take control of your time, tasks and talents.* New York, NY: St. Martin's Press.

Schmidt Neven, R., Anderson, V., & Godber, T. (2002). *Rethinking ADHD: Integrated approaches to helping children at home and at school.* Crows Nest, NSW, Australia: Allen & Unwin.

Section 3: Applying Sensory Integration Principles for Children with Autism Spectrum Disorder

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Background and Rationale for Applying Sensory Integration

ASD is one of the most frequently occurring neurodevelopmental disorders in children, with current prevalence estimates suggesting that 1 in 68 children have an ASD diagnosis (Centers for Disease Control and Prevention, 2014). Current diagnostic criteria for ASD (APA, 2013a) include consideration of four main areas: (1) Symptoms of ASD must be present in early childhood; (2) symptoms must limit functional abilities; (3) symptoms must include deficits related to social-communication and social-interaction skills; and (4) symptoms must include restricted, repetitive behavior or interests that are related to two or more of the following: stereotypy in speech or motor actions, excessive routines or patterns of behavior, intense and unusual interests, and hyper- or hypo-reactivity to sensation or unusual sensory interests. Basic diagnostic criteria are shown in Table 19-2.

The recent change in diagnostic criteria for the *DSM-5* (APA, 2013a) for the first time acknowledges and recognizes the frequency with which sensory processing differences and challenges are reported in people with ASD. However, such differences in sensory processing have long been documented in infants and children with ASD (e.g., Ornitz & Ritvo, 1968). Accordingly, clinical practices to evaluate and treat sensory symptoms have received renewed interest.

Sensory Integration and Occupation-Based Challenges

Most children with ASD have some type of sensory processing differences, although prevalence estimates vary. According to parent responses using a variety of parent-report assessments, 45% to 90% of children with ASD are identified as displaying unusual responses to sensory stimuli (Baranek, David, Poe, Stone, &

TABLE 19-2 ***DSM-5*** **Diagnostic Criteria for Autism Spectrum Disorder**

PERSISTENT DEFICITS IN SOCIAL COMMUNICATION AND SOCIAL INTERACTION ACROSS MULTIPLE CONTEXTS	RESTRICTED, REPETITIVE PATTERNS OF BEHAVIOR, INTERESTS, OR ACTIVITIES
Manifestation, Current or by History, as Deficits in	**Manifestation, Current or by History, as**
• Social-emotional reciprocity (e.g., failure to initiate or respond to social cues) • Nonverbal communication used for social interactions (e.g., deficits in use or understanding of gestures, lack of facial expression) • Developing, maintaining, and understanding relationships (e.g., lack of interest in peers; difficulty sharing in play)	• Stereotyped or repetitive movements, use of objects, speech (e.g., lining up toys) • Insistence on sameness, inflexible adherence to routines, or ritualized patterns or verbal and nonverbal behavior (e.g., distress with small changes, difficulties with transitions) • Highly restricted, fixated interests of abnormal intensity or focus (e.g., preoccupation with unusual objects) • Hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment (e.g., adverse response to sound or touch; excessive smelling or touching)
• Symptoms must have been noted in early development but might not have been fully demonstrated until demands from the social environment were increased. • Symptoms must impair current occupational, social, or other important areas of function. • Concerns must not be better explained by other diagnosis, although ASD can coexist with other diagnoses (e.g., ADHD, intellectual disability).	

Adapted from the American Psychiatric Association. (2013a). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Watson, 2006; Leekam, Nieto, Libby, Wing, & Gould, 2007; Tomchek & Dunn, 2007; Watling, Deitz, & White, 2001). Similarly, motor and praxis symptoms are frequently reported and have been studied (Baranek, 2002; Dawson & Watling, 2000; Smith Roley, Parham, Mailloux, Schaaf, & Cermak, 2014).

Although the majority of the literature identifies sensory processing patterns along a continuum of over- or under-responsivity (Ben-Sasson et al., 2009; Rogers & Ozonoff, 2005), referred to as "sensory modulation," others have identified patterns related to specific sensory modalities, such as taste-smell sensitivity (e.g., A. E. Lane, Young, Baker, & Angley, 2010) or auditory hypersensitivities. Others have noted difficulties in sensory discrimination and praxis (Smith-Roley et al., 2014), and poor or delayed motor imitation (characteristic of dyspraxia) is commonly cited as a problem seen in children with ASD (Fig. 19-6). Other lines of inquiry have identified postural and praxis-related differences in children with ASD, and that atypical sensory processing and integration may underlie fine motor, gross motor, and gait dysfunctions seen in children with ASD (e.g., Bhat, Landa, & Galloway, 2011). Occupational therapists focus on occupational performance in daily life activities. In children with ASD, differences in sensory

FIGURE 19-6 Tasks such as walking over a block require both postural control and praxis, which is often problematic for children with ASD. *Photo courtesy of Meghan Hall.*

responsivity have been linked to reduced participation in a variety of occupational areas, such as social participation, play, and performance of self-care skills, such as bathing, dressing, and feeding (Ashburner, Ziviani, & Rodger, 2008; Baranek, 2002; Leekam et al., 2007; Rogers & Ozonoff, 2005).

Evaluation and Intervention

Assessment of sensory integrative function in children with ASD can be accomplished using the SIPT, tools addressing sensory modulation, and clinical observations. These approaches are presented in Chapter 9 (Using Clinical Observations within the Evaluation Process) and Chapter 10 (Assessing Sensory Integrative Dysfunction without the SIPT), respectively. Additional information on assessing a child with ASD can be found in Chapter 21 (Planning and Implementing Intervention: A Case Example of a Child with Autism), in which detailed information is presented on a child with ASD.

One common approach to addressing sensory symptoms in children with autism is using ASI. Ayres (1972) proposed that information from the tactile, vestibular, and proprioceptive systems were important substrates for adaptive responses and that difficulty processing and integrating sensations from the body and environment contribute to disrupted or disorganized motor skills and adaptive behaviors. Occupational therapy using SI (OT/SI, also termed ASI) focuses on improving sensory symptoms that impact behavior and addresses underlying sensory and motor factors that may be affecting occupational performance. Practice patterns indicate that nearly 99% of occupational therapists treating children with ASD use a sensory-integrative frame of reference for evaluation or treatment (Watling, Deitz, Kanny, & McLaughlin, 1999), although only 29% indicate that they use ASI specifically, as opposed to other sensory approaches (Ashburner, Rodger, Ziviani, & Jones, 2014).

ASI is directed by a set of principles that includes opportunities for safe, child-directed, sensory-rich, playful interactions that are tailored to the child's need; the art and science of intervention are described in Chapter 12 (The Art of Therapy) and Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), respectively. Interventionists using SI consider a child's strengths and areas of need based on a comprehensive evaluation, as well as motivational interests and desired outcomes, including long-term and short-term goals for treatment. When working with a child with ASD, therapists utilizing the ASI approach may initially have difficulty when identifying motivating, playful opportunities for interaction within the treatment environment given that diagnostic criteria include restricted and repetitive interests and challenges with social-communicative skills. However, therapists are encouraged to use the child's specific interests in planning and implementing treatment. Similarly, some therapists may use sensory-based interventions that are not fully in line with accepted SI tenets. Such sensory stimulation (or sensory-based) interventions may include weighted vests (Fertel-Daly, Bedell, & Hinojosa, 2001; Olson & Moulton, 2004a, 2004b; VandenBerg, 2001) and brushing (Davis, Durand, & Chan, 2011; Kimball et al., 2007). Although these interventions are used to stimulate certain sensory systems, these interventions do not focus on the active involvement of the children in sensorimotor activities challenging tactile, proprioceptive, and vestibular systems that are essential to the SI approach (Ayres, 1972, 1979). Although a complete review is outside the scope of this chapter, therapists should recognize the difference between sensory-based interventions relying on sensory stimulation with passive application of sensation and OT/SI, which abides by the elements of ASI, as described by Parham and colleagues (2007, 2011). Understanding the differences in these approaches and the specific evidence for these different approaches is addressed in the text that follows.

Research on the evidence supporting the use of SI with children with ASD is available, and readers are encouraged to seek systematic reviews that fully examine published research on SI treatment and sensory-based treatment in children (e.g., Case-Smith et al., 2014; May-Benson & Koomar, 2010).

Emerging evidence suggests that using a sensory integrative approach and abiding by tenets as proposed by Ayres (1979) and explicated by Parham and colleagues (2011) may positively influence functional outcomes of children with ASD. Currently, two small randomized controlled trials (higher level evidence) (Pfeiffer et al., 2011; Schaaf et al., 2013) demonstrate significant improvement on parent-identified functional goals following OT/SI for children with ASD compared with usual care (Schaaf et al., 2013) or fine motor treatment (Pfeiffer et al., 2002). Lower level evidence also supports the use of OT/SI, as a recent observational cohort study (Iwanaga et al., 2013) found differences in functional outcomes for the OT/SI group compared with children receiving unspecified group therapy (Iwanaga et al., 2013). In contrast, Watling and Dietz (2007) did not find an effect of SI on engagement in tasks or a reduction in undesired behaviors in young children with ASD following short-term exposure to ASI in a single-subject alternating treatment design. Additional evidence from case studies using OT/SI suggest that these approaches may impact the participation of some children with ASD (Linderman & Stewart, 1999; Schaaf, Hunt, & Benevides, 2012; Schaaf & Nightlinger, 2007; Van Rie & Heflin, 2009). One systematic review has evaluated the evidence related to sensory-based interventions and SI treatment for children with ASD (Case-Smith et al., 2014) and reported that there is promising evidence for SI treatment. Overall, findings from both higher and lower level evidence suggest positive effects for OT/SI on functional, participation-based goals for children with ASD. More information on SI intervention and children with ASD can be found in Chapter 15 (Advances in Sensory Integration Research: Clinically Based Research) and Chapter 16 (Advances in Sensory Integration Research: Basic Science Research), respectively.

In contrast, research examining sensory-based approaches that rely on passive application of sensation to children, such as weighted vests, brushing, or spinning protocols, have limited evidence supporting their use (Case-Smith et al., 2014). Typically, these approaches are used in settings in which traditional OT/SI is not feasible (e.g., treatment occurring in a school). Therapists seeking to use sensory-based approaches should consider whether these treatment choices are justified given their lack of supporting evidence, and therapists using these approaches should carefully collect data on their intervention and child's response and document objective outcomes consistently. As with any occupational therapy treatment, regular tracking of data on outcomes will assist a therapist in modifying or adjusting a treatment plan to better meet the long-term goal(s) of the child and family.

CASE STUDY ■ MARTIN

Martin, a young child diagnosed with autism at 18 months of age, was enrolled in early intervention from 9 months of age because of delays in gross motor, communication, and socialization skills. At 20 months of age, Martin was seen twice a week in his home with his mother present. The home environment offered multiple opportunities for sensory-rich experiences in tactile, vestibular, and proprioceptive activities in keeping with ASI principles. The therapist, upon referral, assessed the family's routines and areas of occupational need. For example, Martin's mother identified that eating a wider repertoire of foods, tolerating a toothbrush, ability to go into the community, and playing interactive games with the family were areas of importance. To further assess whether difficulty processing and integrating sensory information was a factor affecting these participation challenges, the Infant/Toddler SP (Dunn & Daniels, 2002) was used to identify possible areas of sensory responsivity that were impacting daily routines. Observation of the child in his natural environments (e.g., home during mealtimes, home during play, home during morning routines, backyard during outside play, at the playground, and in the grocery store) afforded the therapist opportunities to observe the sensory qualities of the environment and the parents' reported dilemmas in caregiving and play. Lastly, the therapist used playful opportunities, such as play with food textures and outdoor play equipment, to evaluate Martin's responses to tactile, proprioceptive, and vestibular input within the natural environments and to assess his praxis abilities and postural control.

Assessment results were used to generate hypotheses regarding the specific sensorimotor factors affecting Martin's occupational performance problems. The therapist also identified child, family, and environmental factors that appeared to be contributing to his difficulties, and importantly, identified Martin's strengths and areas of interest. Although this case emphasizes specific child factors assessed using a sensory integrative frame of reference, it is important that occupational therapists also examine the intersection of the child, environment, and his or her occupations using other frames of reference that may be appropriate (Ashburner et al., 2014). Martin's interests and strengths at 20 months of age included engaging with puzzles and animal figurines, and Martin had a fascination with bubbles and other repetitive visual stimuli (e.g., ceiling fans). Assessment data revealed that Martin had tactile hypersensitivity, especially around the hands and mouth; that he did not like movement activities, preferring seated activities (e.g., puzzles, animals); and he was sensitive to environmental stimuli, especially situations with a lot of visual stimuli and noise. These sensory rich environments often resulted in increased self-stimulation behaviors, crying, or "meltdowns." Additionally, similar to many young children with ASD, Martin rarely made eye contact, did not use words, and did not use gestures to communicate his needs. Martin displayed difficulties with ideation and motor planning and with delayed fine and gross motor skills, which were particularly evident during play and feeding.

Intervention was targeted at enhancing the home environment to provide needed sensory experiences and develop self-regulation strategies and skills for use in community settings that were challenging for Martin, such as the playground and grocery store. For example, upon recommendation from the therapist, the family brought a Playskool® toddler slide from the basement up to the living room with the dual goal of addressing the child's sensory and motor needs and the parents' participation goals (social play). The therapist worked with Martin's mother using the Playskool® slide to engage Martin in motor challenges in order to address motor planning skills (praxis) and to work on vestibular processing and postural control. For example, the therapist and parent team encouraged Martin to engage in supported climbing onto the slide in search of animals (or puzzle pieces) (Fig. 19-7) and to slide down (with support) (Fig. 19-8) into a pile of pillows with an immediate "squish" (deep pressure touch input). Martin found this to be challenging, but enjoyable, and this activity often resulted in brief periods of eye contact with mom after coming out of the pillows. Such activities also provided Martin with opportunities to process proprioceptive and tactile input. As his ability to successfully navigate this sensorimotor challenge increased, and his mother became comfortable with facilitating her son's sensorimotor skills, additional items were added into the play situation, such as large chair beanbags, a tunnel (Fig. 19-9), and foam blocks. These were incorporated as objects to step on (challenging vestibular), to crawl over (challenging proprioception), or to crash into (challenging tactile), as well as to challenge his motor planning abilities (e.g., navigating through the tunnel connected to the playhouse). At a participation level, Martin developed reciprocal play interactions with his mother and both Martin and his mother engaged in positive affect, including smiling and physical touch (Fig. 19-10).

FIGURE 19-7 Providing physical cues of the body in space without "doing for" the child as he climbs. *Photo courtesy of Meghan Hall.*

Intervention goals were developed collaboratively with Martin's mother and the interdisciplinary team and included that Martin would

FIGURE 19-8 Modeling trunk support with a toy slide (vestibular challenge). *Photo courtesy of Meghan Hall.*

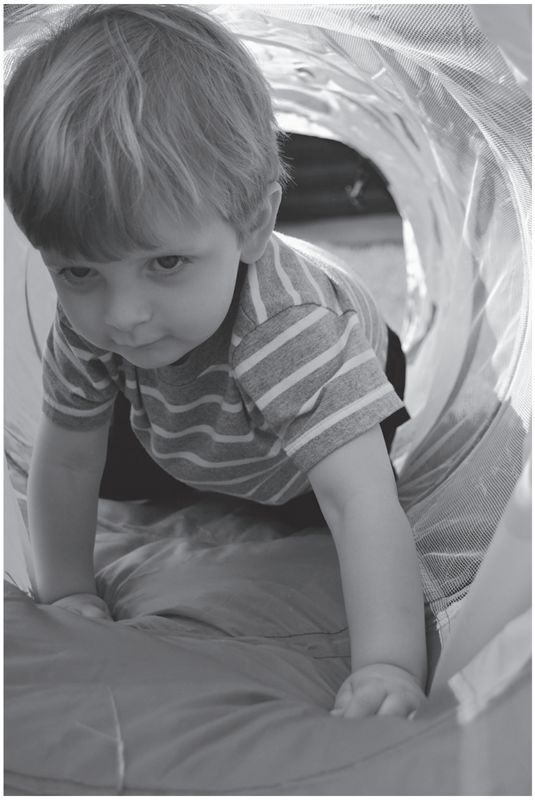

FIGURE 19-9 Motor planning how to navigate the tunnel. *Photo courtesy of Meghan Hall.*

eat a wider repertoire of foods, tolerate a toothbrush, be able to participate in the community (e.g., playground, grocery), and play interactive games with the family. During the course of twice-weekly sessions performed during an 18-month period, Martin progressively used more spontaneous eye contact during preferred sensory play and during activities that were non-preferred, such as walking barefoot on an indoor or outdoor mat to get to the slide. He also began to spontaneously use signs and gestures that he was learning in speech therapy, such as "more" to communicate with his mother (Fig. 19-11). Additionally, Martin improved in his ability to process and integrate sensations for motor challenges that were introduced and was more willing to try new activities requiring motor play, such as using unfamiliar playground equipment with novel climbing structures in the community.

FIGURE 19-10 Demonstrating positive affect and engagement during the "squish" activity. *Photo courtesy of Meghan Hall.*

HERE'S THE POINT

- Most children with ASD have some SI challenges. Several small randomized controlled trials and a systematic review suggest there is sufficient evidence to support the use of an SI approach to address sensory-based challenges,

FIGURE 19-11 Fist bump for a job well done! Shared affect and touch without eye contact is accepted. *Photo courtesy of Meghan Hall.*

although sensory-based approaches such as weighted vests have not been supported by research.
- Sensory modulation challenges, sensory discrimination dysfunction, and sensory-based motor problems including dyspraxia and postural disorders are commonly seen in children with ASD.
- Principles of SI, such as child-directed, playful activities that incorporate rich opportunities for tactile, proprioceptive, and vestibular experiences, can be provided in home, community, and clinic environments.
- Most of the research examining the effectiveness of ASI has been done with samples of children with ASDs, and the evidence suggests that the treatment approach is effective at addressing parent-related goals in clinic-based settings, although more research is needed on the use of this approach in home and community environments.

Where Can I Find More?

The following two articles provide a deeper understanding of the sensory-related issues in autism. They reflect only a small bit of the ongoing research in this area.

Schauder, K. B., & Bennetto, L. (2016). Toward an interdisciplinary understanding of sensory dysfunction in autism spectrum disorder: An integration of the neural and symptom literatures. *Frontiers in Neuroscience, 10*(JUN), 1–18. doi:10.3389/fnins.2016.00268

Tavassoli, T., Bellesheim, K., Siper, P. M., Wang, A. T., Halpern, D., Gorenstein, M., . . . Buxbaum, J. D. (2016). Measuring sensory reactivity in autism spectrum disorder: Application and simplification of a clinician-administered sensory observation scale. *Journal of Autism and Developmental Disorders, 46*(1), 287–293. doi:10.1007/s10803-015-2578-3

Section 4: Sensory Integration and Children with Disorders of Trauma and Attachment

JoAnn Kennedy, OTD, MS, OTR/L

Background and Rationale for Applying Sensory Integration

During recent decades, biological and clinical evidence has shown that childhood **trauma** and inadequate parent-child attachment profoundly impact the health and function of individuals into adulthood (Bowlby, 1988; Karen, 1998; van der Kolk, 2006). Koomar (2009) reported that occupational therapists using the SI model frequently treat children who have experienced traumatic events that impede healthy social attachments. This situation is caused by the high prevalence of childhood trauma in general (National Child Traumatic Stress Network, n.d.) and also the shared features of sensory modulation disorders with disorders of trauma and attachment (DTA). Although these same sensory features can present similarly in children with sensory modulation disorders associated with other conditions, those related to DTA require a different treatment approach termed **trauma-informed care (TIC).** TIC is an approach used across many health and education disciplines. In occupational therapy, TIC requires therapists to be aware of, and consider the signs of, DTA. This includes conducting thorough evaluations to identify possible trauma in client histories, ongoing efforts to avoid re-traumatization of the client, use of techniques that support recovery from trauma, and interventions to help develop secure relationships with attachment figures (Champagne, 2011a). Direct involvement of caregivers in therapy sessions, for example, is often a priority in occupational therapy treatment using SI with children with DTA.

Under optimal conditions, infants and their caregivers form strong social attachments as parents accommodate to their baby's first needs for sensory comfort and stimulation. When infants sense discomfort or a need for stimulation, they signal those needs through vocalizations (fussing, crying, cooing) or gestures (eye contact, reaching, head turning). When the caregiver satisfies the infant's need, both of them are gratified and gain trust in each other as individuals. With repeated experience, the dyad becomes increasingly adept at signaling and meeting one another's needs. A positive attachment cycle (Fig. 19-12) develops, leading to a secure attachment pattern. This provides a foundation for healthy social and emotional functioning throughout life. Animal research also indicates that optimal attachment formation depends on species-specific sensory inputs from the caregiver to the infant during sensitive periods of development (Kaffman & Meaney, 2007; Panksepp, 2004).

Additional findings from clinical and animal research show that early trauma or insensitive care often leads to anxious attachment patterns (Karen, 1998). Anxious attachment patterns can be ambivalent, causing a child to signal dependence excessively, or avoidance, leading to independence beyond the child's overall developmental readiness. Figure 19-13 depicts how through time a negative attachment cycle becomes short-circuited, eventually leading to anxious attachment patterns. Children with anxious attachments struggle to form satisfying friendships and positive relationships with authority figures.

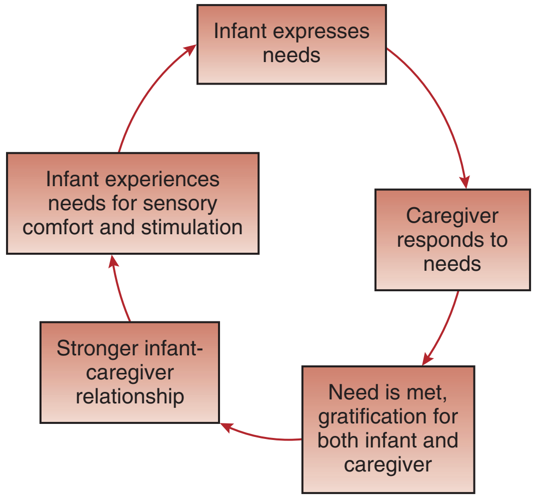

FIGURE 19-12 A positive attachment cycle is the foundation for a secure attachment pattern.

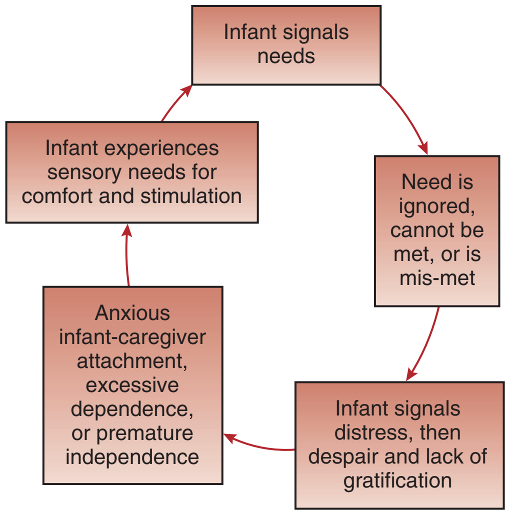

FIGURE 19-13 A negative attachment cycle (initial infant signals do not lead to sufficient care) is short-circuited (red arrows), leading to excessive dependence or independence.

Severe or ongoing trauma frequently results in a disorganized attachment pattern characterized by contradictory, fearful behaviors (Bowlby, 1988); sometimes this leads to one of many trauma- and stress-related disorders as defined in the *DSM-5* (APA, 2013a). One such disorder is referred to as **reactive attachment disorder (RAD)**, and it is very relevant to children with DTA. The hallmark of this internalizing disorder is an inability to seek or be comforted by adequate caregivers because of insufficient care during infancy or early childhood. Disinhibited social engagement disorder (DSED) also stems from inadequate early care but results in externalizing behaviors characterized by overly familiar or indiscriminant socialization. Post-traumatic stress disorder (PTSD) is another stress-related disorder these children may face. There is a set of diagnostic criteria for older children, adolescents, and adults, and separate criteria for children 6 years of age and younger (APA, 2013a). Children with PTSD often have tantrums, nightmares, episodes of staring or freezing, exaggerated startle responses, reenactment of trauma during play, or avoidance of reminders (including sensations) of the trauma. Because sensory processing problems often accompany or co-occur in children with DTA, occupational therapists working with such children should consider applying SI approaches.

Sensory Integration and Associated Occupation-Based Challenges

Occupational therapists frequently treat children who have DTA caused by neglect, abuse, inconsistency of caregivers, or comparable experiences suffered during treatment for medical conditions (Koomar, 2009). Several types of sensory disturbances are typical of DTA. Infants who do not receive or benefit from regular sensory stimulation that is responsive to their needs for emotional and physiological regulation often engage in extensive rocking, pulling at objects or body parts, or pounding on hard surfaces. These repetitive, sensory-seeking behaviors can continue as self-regulatory mechanisms, even after the child receives more supportive care. Sensory seeking behavior is problematic when it interferes with regulation through an attachment figure, is destructive, or interferes with the child's ability to complete other desired or important tasks and activities.

Another sensory problem common among individuals who have experienced severe traumatic events is hypervigilance—a continual monitoring of the environment to detect and avoid additional trauma (van der Kolk, 2006). Visual and auditory hypervigilance can shift awareness away from the individual's own body, causing functional impairments similar to somatosensory under-responsivity of other origins. It can also impede attention and focus on more important or salient tasks, and, therefore, it must be differentiated from attention disorders of other etiologies. Individuals who have DTA can experience trauma triggers, which are specific sensations or reminders of past trauma that prompt periods of physiological or emotional dysregulation. Common examples of trauma triggers are the odor of liquor, angry facial expressions, and touch to body parts that have been painfully injured. These behavioral responses differ from SOR, which is associated with a broader category of sensations (Koomar, 2009). Increasingly, leaders in the field of trauma recovery are recognizing these sensory features of DTA and the need for sensory treatments (B. D. Perry, 2009; van der Kolk, 2006).

In humans, multisensory stimulation may buffer babies from some inadequacies of institutional care (T. I. Kim, Shin, & White-Traut, 2003). Laboratory animals that experience conditions analogous to inadequate infant care or PTSD respond to enriched environments with emotional, social, and cognitive recovery (Hendriksen, Prins, Olivier, & Oosting, 2010; Kaffman & Meaney, 2007). These functional improvements are attributed to neural plasticity, especially in the hippocampus and amygdala of the brain. Enriched animal environments share many features with SI intervention, including varied, novel, and complex sensory experiences; active, enjoyable social engagement; and physical and emotional safety (S. Reynolds, Lane, & Richards, 2010). This basic research supports use of SI and other sensory-based techniques as part of an occupational therapy program for children with DTA.

Evaluation and Intervention

Because children with DTA and their families have complex needs, they often require assessment and intervention from multiple perspectives. Assessment from a sensory integrative perspective should address sensory modulation and discrimination, as well as praxis; these children present with complex needs. Specific information on assessment of sensory integrative concerns can be found in Chapter 9 (Using Clinical Observations within the Evaluation Process) and Chapter 10 (Assessing Sensory Integrative Dysfunction without the SIPT). Intervention is often best when it combines approaches that address sensory and regulatory needs, is relationship based, and includes caregiver education. For instance, Wells and colleagues (2012) studied 78 children between 6 and 11 years of age who were exposed to alcohol prenatally and removed from their birth families. Treatment of the experimental group was an adaptation of the sensory-based Alert Program® (Williams & Shellenberger, 1996), with concurrent parent training on effective management of children with executive dysfunction and sensory dysregulation. Compared with controls, the experimental group achieved significantly greater improvements in executive and emotional functioning.

In her seminal work of 1975, Jean Ayres briefly addressed children with emotional problems and advised: "In this case a revised plan with more direction and structure with considerable support may be required" (p. 265). Children who have not experienced consistent physical and emotional security or responsive care often need support in choosing and safely engaging in SI activities. For example, children who have obtained adult attention mainly through negative or self-abusive behavior may take excessive risks on suspended equipment, threatening their own safety. A child with PTSD may use therapy equipment to re-play themes from past trauma in unproductive ways or may be inadvertently triggered into traumatic flashbacks by sensations during treatment. For children with insufficient attachment, especially those who are indiscriminately affectionate, their caregivers or primary attachment figures should participate in therapy and they, rather than the therapist, should become the primary source of positive sensory experiences. Finally, therapist self-care is essential for working with this population. To empathize with children who have DTA while maintaining their own emotional regulation, therapists must have knowledgeable, sensitive support from TIC-experienced mentors and colleagues (Koomar, 2009). The following is a case study to illustrate how SI principles may be applied to a child who has experienced trauma.

CASE STUDY ▪ TED

Ted and his twin brother were born at 25 weeks gestation. Sadly, his brother died a few days later. Ted experienced considerable physical pain caused by complex medical problems and multiple surgeries. In addition, staff in the NICU told his parents that touching Ted might cause him discomfort. After spending his first 6 months in the hospital, Ted continued to be fed by a gastric tube at home and to receive daily therapies supporting oral, sensory, motor, and cognitive development. His parents were very involved in this process. Ted walked at 3 years of age, and he transitioned fully to oral feedings at 5 years of age. Just before starting kindergarten, he became gradually more emotionally dependent on his parents. He required several hours of undivided attention to fall asleep. He complained at length about minor injuries, though he habitually picked at his hands and surgical scars, sometimes causing bleeding. He actively explored familiar places but insisted on being carried when the family was out in the community and would not attempt to use playground equipment independently.

At this point, Ted's parents sought occupational therapy intervention at a community-based clinic. Their immediate goal was to increase Ted's independence at his new school building and playground. They were also concerned about his dependence for self-feeding, dressing, and at bedtime. Sue, his occupational therapist, performed the initial occupational therapy evaluation, which showed that Ted was over-responsive to vestibular sensations. He was stressed when asked to jump or climb, and he lacked equilibrium responses when on mobile therapy equipment. In addition, he avoided textures and was not soothed when held by his parents. Sue's clinical reasoning led her to the hypothesis that Ted's needs for soothing and stimulation were not met satisfactorily during his early infancy because of his medical conditions. This situation, combined with his over-responsivity to movement, led to emotional dependence that limited his motor exploration.

His parents also revealed that they had never talked with Ted about his brother's existence or death. Sue explained how a history of neonatal pain, and limited tactile stimulation, along with Ted's vestibular over-responsivity, could be hindering his current emotional and motor development. She advised that a mental health consultation would help the family process the challenging emotional issues surrounding Ted's birth and the loss of his brother. His parents and therapist agreed that an initial goal was to help Ted modulate movement and tactile sensations as a foundation for more mature motor and emotional skills. Sue affirmed Ted's parents' accomplishments in fostering his progress during the past years.

Initial occupational therapy sessions focused on using different types of equipment for Ted to explore and to expand the amount of movement he could comfortably process. For example, Ted enjoyed rolling prone over a peanut ball wedged between large cushions, which allowed him to experience lifting his feet from the floor in a predictable and limited rocking motion (Fig. 19-14). He asked to repeat variations of this activity during a dozen sessions. Sue coached his father to encourage this exploration and to intermittently provide firm touch in rhythm with Ted's rocking. She added tactile materials near the barrel and other equipment that Ted readily explored. Each time Sue invited Ted to use a new swing or scooter board, he protested extensively, although Sue knew he had enjoyed almost identical sensory experiences.

His parents initiated mental health support, including some counseling, and with guidance, they told Ted about his brother. Gradually the combination of mental health and occupational therapy interventions seemed to be having the desired effects. Ted began to trust his own sensorimotor abilities and his parents' judgments about trying new things. Slowly he began trying equipment on playgrounds where he previously would not go, including pumping swings, and he used the neighborhood pool. Sue also worked with his mother, showing her how to provide deep pressure massage to Ted's back in a consistent, rhythmic pattern at bedtime. After this tactile input, his parents implemented their counselor's recommendations to sit next to his bed without interacting while Ted fell asleep. Through several months his parents gradually sat farther away until they could stay in the next room as he drifted to sleep. With improved sensory processing and family relationships, Ted became more adventurous and independent across all settings. Six months later, he needed only occasional occupational therapy consultations.

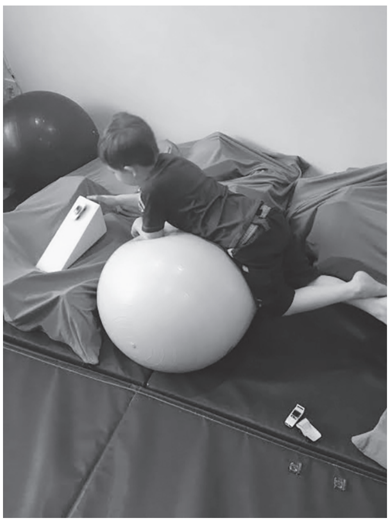

FIGURE 19-14 Ted prone on the peanut ball as he begins to feel secure enough with movement to lift his feet from the mat and engage in play. *Photo courtesy of Tracey Hulen.*

HERE'S THE POINT

- SI intervention techniques are a valuable part of the recovery process for many children with DTA.
- All professionals serving this population need to be knowledgeable regarding normal sensory, social, and emotional development as well as the difficulties trauma and poor attachment pose.
- Professionals working in this area will need collegial support on both technical and emotional levels for this extremely challenging work.
- Jean Ayres (1975) foresaw a time when the fields of SI and mental health would join forces. Scientific and clinical evidence now affirm the importance of sensory interventions in trauma and attachment work.

Where Can I Find More?

Gaskill, R. L., Perry, B. D., Malchiodi, C., & Crenshaw, D. A. (2013). The neurobiological power of play. In E. Cathy Malchiodi & David A. Crenshaw (Eds.), *Play and creative arts therapy for attachment trauma* (pp. 2–22). New York, NY: Guilford Press.

Ryan, K., Lane, S. J., & Powers, D. (2017). A multidisciplinary model for treating complex trauma in early childhood. *International Journal of Play Therapy, 26*(2), 111–123. doi:10.1037/pla0000044

Section 5: Sensory Integration Applications with Adults

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Background and Rationale for Applying Sensory Integration

Adults with SI and processing issues are an underserved and underidentified group despite an emerging body of literature supporting the presence of sensory processing deficits in adult populations. Some children identified with sensory processing disorder continue to exhibit sensory processing and integration problems as adults, although the idea of sensory processing disorder as a lifelong condition has not been adequately researched. Some individuals are only first identified with the disorder in adulthood, although upon history taking, it is almost always the case that adults share experiences suggesting that sensory processing differences were also present throughout their childhood. There has been some work indicating that sensory processing problems can occur in the general adult population among adults with no known comorbid or co-occurring mental or physical health conditions (Kinnealey & Fuiek, 1999; Kinnealey, Koenig, & Smith, 2011; Kinnealey, Oliver, & Wilbarger, 1995; Pfeiffer & Kinnealey, 2003). In this section, evidence suggesting the presence of sensory processing disorders in adulthood is discussed, along with some general ideas and principles for evaluating and intervening with adults following an SI approach.

The etiology of sensory processing disorder is largely unknown, but it may be related to a genetic predisposition or other medical conditions. In addition, some adults with sensory processing disorders may view their symptoms simply as part of their constitutional makeup, or as an aspect of their behavior, personality, or temperament. Such individuals often do not understand how it is to live without SI and processing issues because they have no basis for comparison, despite a feeling that they experience sensations throughout their daily lives differently from others. It is common for many adults with sensory processing differences to experience a sense of relief in learning that there is a name for the discomfort or awkwardness they experience, and that there are others who are challenged by the same or similar sensory processing symptoms. Adults with sensory processing differences often develop effective coping mechanisms such as avoiding or preparing for situations that they anticipate would be uncomfortable or challenging for them although these techniques are often exhausting and time consuming (Kinnealey et al., 1995; Koomar, 2012). Although some coping mechanisms enable adults to "get through the day" or recuperate from difficult situations more quickly, these techniques do not entirely relieve the problem, and often these sensory processing differences continue to hinder quality of life.

Sensory Integration and Associated Occupation-Based Challenges

There is a significant amount of literature supporting the presence of SI and processing disorders in adults within clinical groups (Crane, Goddard, & Pring, 2009; Davidson, 2010, Lyoo et al., 2006; Yeap, Kelly, Reilly, Thakore, & Foxe, 2009), as well as in individuals without any clinical diagnoses (Kinnealey & Fuiek, 1999; Kinnealey et al., 1995). One of the first explorations of sensory processing disorders in adults was a qualitative, phenomenological study with non-clinical adults (Kinnealey et al., 1995). The authors described the subjective reality of five adults with defensive responses to environmental stimuli and their coping strategies and then proposed a conceptual framework for understanding this population. From this work, assessment tools were developed, including the Adult Sensory Questionnaire (ASQ), a screening tool, and the Adult Sensory Interview (ADULT-SI), a 75-item, open-ended, scored interview (Kinnealey & Oliver, 1999) for examining behaviors associated with sensory processing in adults.

The validity of sensory processing deficits as being a condition that may be present in some adults was also addressed by examining the neurophysiological basis of the disorder in adults with and without sensory defensiveness (Kinnealey & Smith, 2002). These researchers found differences between adults who are sensory defensive and non-sensory defensive on the variables of heart rate variance and skin conductance reactivity.

In addition to existing in adults without other known disorders, sensory processing and integration disorders may coexist with some conditions that are known to occur throughout the life span, such as intellectual impairment, ASD, and ADHD. For example, sensory processing differences in adults with ASD have been described by Crane, Goddard, and Pring (2009); Davidson (2010); Leekam and colleagues (2007); and W. Perry and colleagues (2007). Several adult-onset mental health conditions, such as schizophrenia (see Jahshan et al., 2012), bipolar disorder (see Lyoo et al., 2006; Yeap et al., 2009), and conditions associated with anxiety (see Ludewig et al., 2005), have also been associated with sensory processing problems. It can also be associated with PTSD, traumatic brain injury, or sequelae to violence, such as torture, abuse, or deprivation.

Researchers have begun to explore and describe the impact of SI and processing disorders in the lives of adults. Kinnealey and Fuiek (1999), for example, identified differences in anxiety, depression, and psychological adjustment between adults with and without sensory defensiveness. May-Benson and Patane (2010), in a retrospective review of medical records, found social-emotional difficulties, anxiety and over-arousal, and functional motor and organization problems as being common problems associated with sensory processing deficits in adults. A case study report by Pfeiffer (2002) explored the impact of SI and processing disorder on occupations in childhood through adulthood; she found that many of the occupational roles and choices of the individual were influenced by SI and processing disorder. She concluded that meaningful interventions must address not only the primary sensory disorder but also the secondary impact on the person's occupations. Kinnealey, Koenig, and Smith (2011) explored the relationship between sensory modulation, social supports, and health-related quality of life in adult volunteers matched for age and gender and grouped by sensory over-responsiveness or non-over-responsiveness. Results indicated that sensory response style is significantly and differentially related to symptoms of mental functioning and quality of life, including social participation.

Evaluation and Intervention

The process for evaluating adults should uncover specific sensory processing deficits, as well as any other physical, cognitive, and social-emotional problems affecting the adult's participation in daily life and quality of life (May-Benson & Kinnealey, 2002). There are a few tools developed specifically to assess sensory processing disorders in the adult population, although they all focus primarily on sensory modulation. They include the Adolescent/Adult SP and the ADULT-SI. The Adolescent/Adult SP (Brown & Dunn, 2002) measures sensory modulation through a self-report format standardized for individuals between 11 and 65 years of age. Scores are provided in four quadrants—low registration, sensation seeking, sensory sensitivity,

HERE'S THE EVIDENCE

Kinnealey and colleagues compared 14 adults with SOR with a typical group of adults, all between 18 and 60 years of age, wanting to understand the relationships between SOR, anxiety, depression, perceived social supports, and quality of life. Tools used included the ASQ (Kinnealey et al., 1995) and the Adolescent/Adult Sensory Profile (Brown & Dunn, 2002) to gather information on sensory processing, the Medical Outcomes Social Support Survey (Sherbourne & Stewart, 1991) for perceived social support, the Short Form-36 Health Survey, version 2 (Ware, Snow, Kosinski, & Gandek, 1993) to obtain information on health and well-being, the Beck Depression Inventory-II (Beck & Steer, 1987), and the Beck Anxiety Inventory (Beck & Steer, 1990). The two groups of adults differed significantly on sensory processing (p = .0001), depression (p = .009), anxiety (p = .000), and aspects of health and well-being (bodily pain, p = .012; general health, p = .017; vitality, p = .009; social functioning, p = .042). Among other findings, investigators identified significant correlations between SOR and anxiety (r = .66, p = .001), and, to a lesser extent, between SOR and depression (r = .37, p = .001). Scores on the Adolescent/Adult Sensory Profile (SP) quadrants indicated that sensory sensitivity and sensory avoiding were related to increased anxiety, depression, bodily pain, and decreased general health, vitality, and social functioning. In contrast, sensory seeking was significantly correlated with the quality of life indicators of vitality and general health, and it may serve as a protective factor in reducing the risk of mental and physical health disorders. Investigators suggested that these results could guide therapists toward a focus on health-related quality of life for adults with sensory processing concerns that interfere with occupational performance.

and sensation avoiding—reflecting the combination of a person's neurological threshold (low and high) and behavioral response patterns (active versus passive) to sensory stimuli. The ADULT-SI is administered in an interview format to identify sensory defensiveness and related social-emotional issues, coping strategies, and the extent to which these impact on daily living (Kinnealey & Oliver, 1999).

As with any thorough evaluation, extensive sensory histories and clinical observations are essential to the process. The evaluation process should also include tools that assess performance skills commonly impacted by disorders of sensory processing, including sensory perception, praxis, motor skills, and postural control. Some valuable tools appropriate for use with the adult population include the Quick Neurological Screening Test—3rd Edition (QNST-3; Mutti, Martin, Sterling, & Spalding, 1999), the Development Test of Visual Perception Adolescent/Adult (DTVP-A; C. R. Reynolds, Pearson, Voress, & Frostig, 2002), and the Sensorimotor Performance Analysis (Richter & Montgomery, 1989). There are also tools that assess the adaptive behavior and functional skills that may be negatively impacted by sensory processing deficits, such as the Vineland Adaptive Behavioral Scales II (Sparrow, Cicchetti, & Balla, 2005) and the Adaptive Behavioral Assessment System II (Harrison & Oakland, 2003). Additionally, measures that address self-efficacy and self-identified outcomes, such as the Canadian Occupational Performance Measure (Law et al., 2005) and Goal Attainment Scaling (Kiresuk, Smith, & Cardillo, 1994), are extremely valuable tools when working with adults who are able to identify the most relevant and meaningful outcomes for their quality of life.

Adults benefit from information and tools that they can apply to their lives within their natural environments and everyday routines. Therefore, intervention for adults is more commonly implemented within their natural contexts, as opposed to treatment activities for children, which are often implemented in clinic settings. Sensory activities providing enhanced tactile, vestibular, and proprioceptive input to address specific sensory-based problems that are identified may be provided. However, education to assist adults in understanding the impact of their SI and processing issues on performance of their daily occupations is emphasized. Consultative models of occupational therapy service delivery are commonly used and may focus on the identification of activities that provide the type of sensory stimuli that would help the adult successfully perform his or her daily occupations. Active participation of the adult in all aspects of the intervention planning and implementation process is essential as the adult is viewed as the expert regarding his or her needs, and what is relevant and meaningful in his or her life.

For adults with sensory modulation deficits, direct intervention often includes providing information, resources, and strategies to help compensate for sensory processing challenges by modifying the environment or activities to increase comfort, and to enhance the ability to perform necessary and desired daily activities in the home, workplace, or community. It is helpful for adults to be able to explain how their sensory processing differences affect their behavior and performance, so others can better understand what they are experiencing. This understanding enables adults to advocate effectively for adaptations to the sensory features of their environments (for example, at work) for supporting their performance. For adults who are not able to self-advocate, caregivers may participate in the education process, which will enable them to serve as advocates on behalf of the client.

Sensory-based motor disorders, including dyspraxia, and postural disorders can occur with or without sensory modulation disorders. In complex cases, one-to-one clinic-based intervention may be recommended over a consultation model. When treating adults, it is important for clients to understand not only the nature of their difficulties but also the principles of intervention, which positively influences their motivation to participate in treatment, and to follow through with strategies outside of intervention sessions, including home programs. Adult clients can be taught to identify the type of sensory input, combination of sensory inputs, and the frequency and duration of inputs that work toward improving their SI functions. This knowledge helps adults determine the types of activities that would be of benefit to them, as well as those that they would most likely succeed at doing and would enjoy. For example, an adult's postural and sensorimotor problems, including balance, motor coordination, and oculo-motor control, might be addressed by a martial arts program in the community. Weight training, gym activities, and swimming strengthen core muscles and improve other basic motor foundations that support SI functions. Engaging in a regularly scheduled gross motor activity that the adult finds enjoyable, supplemented with an individualized home program, can be effective.

Somatosensory-based dyspraxia can be addressed by encouraging the adult to engage in heavy work activities that provide increased somatosensory and proprioceptive input and that enhance body awareness. Problem-solving strategies, modeling, or assisting to plan and sequence the steps involved in a challenging task may be helpful. Providing more cortical approaches, such as problem-solving, and suggesting daily organizational tools may be used in combination with SI intervention approaches.

Facilitating adaptive responses is a key feature of SI intervention for both children and adults, and adaptive responses can be achieved by embedding challenging and novel activities into activity routines, given optimal sensory input or supports. Avoidance is frequently used as a coping strategy by adults with sensory-based motor disorders to decrease the risk of experiencing and having to deal with uncomfortable and challenging motor situations. Avoidance behaviors often reduce one's ability to fulfill roles and develop skills, as well as social participation, leading to social isolation and social-emotional problems. Intervention should, therefore, include replacing avoiding strategies with more adaptive strategies that support participation and engagement.

A treatment model largely based on the Person-Environment-Occupation model (PEO; Brown, 2014) was developed for working with adults with sensory processing disorders. This model applies principles of SI to help guide the evaluation and treatment process, including the identification of appropriate therapy outcomes. This model begins with an evaluation process to identify which sensory systems are impacted and how the person's unique sensory processing styles and abilities impact his or her daily self-care and other maintenance activities, emotional functioning, work, sleep, and leisure pursuits. In addition, the client's social supports, social participation, and quality of life are addressed. A scored open-ended interview such as the ADULT-SI (Kinnealey & Oliver, 1999) might be used to gather detailed information describing patterns of behavioral responses to sensory stimuli throughout daily life for developing an intervention plan. The interview may be supplemented by other standardized assessments depending on the individual needs of the person and contextual factors, and clinical observations can also be made during sensorimotor and other physical activities. The process is designed to help the person or his or her family and caregivers achieve insight and knowledge about the adult's sensory makeup, as well as principles of SI that he or she can employ as needed. Intervention activities are then identified and designed through a collaborative process and embedded throughout the adult's day or week in a manner that supports self-regulation and enables the cadre of activities to be performed. A problem-solving process is implemented to achieve a comfortable fit between the individual's sensory styles and needs, as well as the occupations that he or she engages in at home, at work, and during leisure and social activities. Through a collaborative process, the individual and therapist identify activities that are easily integrated into the meaningful occupations of the person.

Effectiveness of the adult intervention model based on the PEO model (Brown, 2014) was supported by a study using a pre- and posttest comparison design of adults with sensory modulation disorder. Results indicated a significant reduction of sensory defensiveness and anxiety from pre- to post-intervention (Pfeiffer & Kinnealey, 2003). The consultative treatment model guided the collaborative development of a protocol that provided insight into sensory defensiveness, regular and daily sensory input, and engagement in meaningful activities providing proprioceptive, vestibular, and tactile sensory input. Participants engaged in the self-treatment protocol for a month.

Kinnealey, Koenig, and Smith (2011) theorized that adults who seek out sensory input frequently engage in active and challenging activities, which may promote fitness and social engagement. It is proposed that this sensory-based predisposition is a protective factor for reducing the chances of illness, whereas the sensory modulation patterns of over-responsiveness and under-responsiveness tend to be associated more often with social emotional problems, such as anxiety, depression, social isolation, and non-participation (Kinnealey et al., 2011; Liss, Timmel, Baxley, & Killingsworth, 2005). The concept of sensory seeking as a protective factor was further supported in a study examining the relationships among adults with different sensory processing patterns, participation in common home and community-based activities, and recovery-oriented outcomes in 95 adults with severe mental illness (Pfeiffer, Brusilovskiy, Bauer, & Salzer, 2014). The adults who had more sensory-seeking behavior, as indicated on the Adolescent/Adult SP, had higher levels of participation and recovery than their peers. Furthermore, adults identified with low sensory registration and higher sensory sensitivity reported less participation and lower levels of recovery than their peers.

CASE STUDY ■ GEORGE

George was an adult who was self-referred for an evaluation after learning about occupational therapy through a colleague at work. He recently graduated from college with a degree in Business and obtained a job in a new area of the country. George had been working only 3 months at the time of his occupational therapy evaluation. He reported that he had a difficult time adapting to his new environment, both at home and at work. He was easily overwhelmed by the noise in the office and his apartment was so disorganized that he was losing important items. His clothing was often disheveled and he was unaware of his appearance to others until someone made a comment at work. Before his recent move, he always lived with family or roommates who helped him with many of these issues. George received learning supports in school when he was younger and received accommodations in college, but he never received occupational therapy services.

George was evaluated using the Adolescent/Adult SP and the QNST-3. He reported his primary concerns as his ability to attend and complete tasks at work, and the lack of organization in his apartment. Results of the evaluation revealed significant auditory over-responsivity, decreased proprioceptive awareness, reduced tactile discrimination, and dyspraxia. This impacted his ability to complete many novel daily activities. For example, his apartment was extremely disorganized as he was not able to perform basic cleaning and straightening up tasks that were new to him. His clothing was often disheveled and, at times, buttons were not aligned properly. This contributed to concerns with his appearance socially and at work. His distractibility impacting work performance seemed most significantly impacted by the level of noise in the environment.

Intervention focused on educating George on his condition and possible SI strategies.

This helped him engage more actively in the intervention process and identify strategies that were acceptable and meaningful for him. Simple environmental adaptations were identified to help George in his work environment. He used noise-attenuating earbuds to block out extraneous auditory stimuli. Additionally, he advocated to have his desk moved to a quieter location in his office. George reported that his work performance, as reported by his peers and supervisors, improved significantly after these small adaptations. George participated in individual occupational therapy sessions to improve overall body awareness, tactile discrimination, and praxis for functional motor tasks. Sessions were provided in both the clinical and home settings. Together with the therapist, he identified activities that provided deep pressure tactile, proprioceptive, and vestibular sensory input for implementation throughout his daily routines. These included activities such as biking and weightlifting at the gym (Fig. 19-15), as these were preferred activities for George. The occupational therapist worked with George in his home settings to instruct him in how to complete novel home care tasks that required advanced praxis skills. They worked together to break down the tasks and added additional sensory feedback as necessary during the performance of the task. For example, although George unpacked the majority of items from his initial move, he was not able to figure out how to break down the moving boxes, which were still in his apartment 3 months later. When he learned how to complete this task, the clutter and disorganization was significantly reduced, which allowed George to focus on more specific home care tasks. After 3 months of occupational therapy using an SI approach, George was able to maintain the organization and cleanliness of his home, increase his work productivity, and improve his personal appearance for work and social events.

FIGURE 19-15 George added weightlifting to his everyday routines as a way to meet his sensory needs. *Photo courtesy of Chris Cline.*

HERE'S THE POINT

- Research studies support the idea that sensory processing problems commonly occur in adult populations with and without coexisting disorders, and that sensory modulation disorders have received the most attention.
- Assessment tools and sensory-based interventions have been designed specifically for use with adults.
- A consultative approach to intervention, designed to minimize exposure to sensory sensitivities and to identify or provide activities and strategies for meeting individualized sensory needs and preferences, as well as for enhancing performance in daily life, may be useful.
- Although there is some relevant research available, there is a dearth of studies specifically examining the effectiveness of SI interventions designed for adults.

Where Can I Find More?

American Occupational Therapy Association. (2011). *Occupational therapy using a sensory integration approach with adult populations, fact sheet.* Bethesda, MD: AOTA.

Blanche, E. I., Parham, D., & Chang, M. (2014). Development of an Adult Sensory Processing Scale (ASPS). *American Journal of Occupational Therapy, 68,* 531–538. doi:10.5014/ajot.2014.012484

May-Benson, T. (2009, June). *Occupational therapy for adults with sensory processing disorders, OT practice.* Bethesda, MD: AOTA.

Section 6: Sensory Integration Approaches with Adults with Mental Health Disorders

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Background and Rationale for Applying Sensory Integration and the Impact on Occupation

During the past decade, SI theory, assessment, and intervention have expanded in scope and application, and are being utilized increasingly with adults with mental health symptoms, disorders, and related behaviors. This section addresses applications with adults with schizophrenia, anxiety disorders, stress-related disorders including PTSD, and mood disorders. First, there is discussion of the types of SI symptoms and associated occupation-based problems characteristic of each of these mental disorders.

Schizophrenia

Schizophrenia is a mental health disorder characterized by **psychosis** that may include delusions, hallucinations, disorganized speech, or grossly disorganized or catatonic behavior. In order to be diagnosed with schizophrenia, behaviors must persist and significantly interfere with occupational performance and participation, and cannot be accounted for by other mental disorders, such as a mood disorder (APA, 2013a). In recent years, there has been an increase in research related to understanding sensory processing in individuals with schizophrenia (Champagne & Frederick, 2011; Javitt, 2009a; Mouchet-Mages et al., 2007). Individuals with schizophrenia show poor sensory gating, or difficulty with sensory filtering, resulting in a diminished ability to inhibit response to irrelevant sensory stimuli (Arnfred & Chen, 2004; Micoulaud-Franchi et al., 2016; Patterson et al., 2008; Vlcek, Bob, & Raboch, 2014). It has been suggested that inadequate gating leads to sensory overload and contributes to difficulties with cognitive process in individuals with schizophrenia. Keil, Roa Romero, Balz, Henjes, and Senkowski (2016) have also suggested that differences in auditory gating correspond to subtypes of schizophrenia, something that may impact treatment approaches. In addition, some researchers have suggested that, given the complexity of schizophrenia, rather than simply a "mental health disorder," it should be considered a neurodevelopmental, biobehavioral, and cognitive disorder with psychiatric symptoms; they indicated that sensory processing deficits contribute substantially to the cognitive concerns (Twamley, Salva, Zurhellen, Heaton, & Jeste, 2008). This later point supports an earlier statement that sensory processing deficits in childhood "may contribute greatly to deficits in higher-order cognition" (Leitman et al., 2005, p. 56). Phillips and Seidman (2008) proposed that difficulties with sensory processing and emotional and behavioral regulation are evident in some individuals before the onset of symptoms associated with schizophrenia. Subsequently, these difficulties may serve as early biomarkers of the disorder.

Deficits in visual processing among individuals with schizophrenia are well documented (Kantrowitz, Butler, Schecter, Silipo, & Javitt, 2009; Silverstein & Keane, 2008). For example, problems with visually decoding facial information and a reduced capacity for recognizing and identifying emotions in others has been demonstrated consistently by Butler and colleagues (Butler et al., 2005; Butler et al., 2007; Butler et al., 2009). Such challenges have been shown to negatively influence the quality of social interactions and social participation in individuals with schizophrenia (Butler et al., 2009; Javitt, 2009a, 2009b). Problems integrating sensory information from the vestibular and visual systems to execute skills such as coordinating eye movement to visually scan and track objects, and to read, have also been identified in people with schizophrenia (Chen, 2011; D. Kim, Wylie, Pasternak, Butler, & Javitt, 2006).

Olfactory discrimination problems were reported by Atanasova, Graux, El Hage, Hommet, Camus, and Belzung (2008) as well as Moberg and colleagues (1999), who suggested that atypicalities in processing odors may be a potential biomarker of schizophrenia. Difficulty with auditory discrimination, such as the ability to match tones, was found to lead to impairments in the processing of phonological information and auditory emotion recognition in adults in schizophrenia (Javitt, 2009a; Leitman et al., 2008; Turetsky, Bilker, Siegel, Kohler, & Gur, 2009; Vinogradov & Nagarajan, 2017). Finally, difficulty with somatosensory processing, including under-responsivity to pain sensations, was reported by Arnfred and Chen (2004) and Chang and Lenzenweger (2005).

Movement-based interventions have been shown to decrease negative symptoms of schizophrenia (Rohricht & Priebe, 2006), suggesting that there is a possible link between vestibular and proprioceptive processing and the underlying processes involved in schizophrenia. Using Dunn's Model of Sensory Processing (Brown & Dunn, 2002), people with schizophrenia were found to have a high neurological threshold for stimulation and exhibit fewer sensation-seeking patterns than most neuro-typical adults in the same age range (Brown, Cromwell, Filion, Dunn, & Tollefson, 2002). Although more research is necessary, this growing body of evidence strongly supports the idea that people with schizophrenia have a variety of sensory processing-related challenges that often interfere with their daily functioning and occupational performance, supporting sensory-based intervention approaches with this population.

Anxiety Disorders

Anxiety disorders refer to a family of disorders characterized by excessive feelings of fear, worry, concern, or apprehension that interfere with one's ability to function. Anxiety disorders include several more specific disorders, such as separation anxiety disorder, social anxiety disorder, panic disorder, agoraphobia, generalized anxiety disorder, and selective mutism (APA, 2013a). Engel-Yeger and Dunn (2011) found that in Western cultures, adults with a high threshold for stimulation (SUR) often experience symptoms of anxiety, shame, guilt, hostility, and irritability. These researchers also found that a pattern of sensory sensitivity was correlated with **trait anxiety,** which is a general level of anxiety that is related to personality and that results in an individual becoming easily stressed and anxious. In contrast, the sensation-avoiding pattern was correlated with **state anxiety** or a state of heightened emotions that develops in response to a fear or danger of a particular situation. Significant correlations have been found between SOR, high anxiety, and difficulty coping with everyday situations (Bakker & Moulding, 2012). Hoffman and Bitran (2007) explored correlations between SOR and social anxiety disorder and revealed that SOR appears to be separate from social anxiety, although it is highly correlated with agoraphobic and harm-avoidance patterns. Although more research is needed, these investigators indicated that individuals with the generalized subtype of social anxiety disorder tended to report higher levels of SOR than study participants with a non-generalized subtype.

Although many studies have supported a relationship between SOR and anxiety, it has also been shown that some people (especially males) with SUR patterns or low sensory registration have a higher probability of trait anxiety, somatization, high levels of distress, feelings of fear and guilt, and preoccupation with body image (Ben-Avi, Almagor, & Engel-Yeger, 2012; Engel-Yeger & Dunn, 2011). According to Jerome and Liss (2005), adults with SUR may be separated into two groups: those who tend to be under-aroused, and those who tend to be hyper-aroused or extremely overwhelmed and then shut down or "tune-out," perhaps as a coping mechanism. Engel-Yeger and Dunn (2011) found that individuals with SUR patterns have difficulty with recognizing and appraising sensory stimuli, which can result in increased anxiety and over-reactivity or a denial of distress and shut down (Engel-Yeger & Dunn, 2011).

For many years, problems with vestibular functioning have been linked to anxiety disorders (Balaban & Jacob, 2001; Jacob, Whitney, Detweiler-Shostak, & Furman, 2001; Simon, Pollack, Tuby, & Stern, 1998; Staab, 2017). Balaban (2002) created a complex model demonstrating the neurological basis linking anxiety and balance. He cited evidence that a vestibulo-recipient region of the parabrachial nucleus (PBN) of the brain contains cells that respond to body rotation and position relative to gravity. He further explained that this area assists in integrating vestibular, somatic, and visceral information, helping to mediate avoidance anxiety and fear responses. Perna and colleagues (2001) also described balance problems as measured by posturography in individuals with panic disorder and agoraphobia.

Trauma and Stress-Related Disorders

Trauma and stress-related disorders, such as PTSD, acute stress disorder, and adjustment and attachment disorders, also are characterized by feelings of anxiety, although they have their own diagnostic category and unique set of criteria (APA, 2013a). Trauma is defined as an individual's experience of circumstances or events that are threatening or harmful, emotionally or physically, and have an adverse influence on a person's physical, emotional, social, or spiritual functioning and well-being (Substance Abuse and Mental Health Services Administration [SAMHSA], 2014). Circumstances and events that are traumatic may be single, repeated, or chronic, and the emotional or physical threat may be actual, witnessed, or perceived. Neglect is also considered a form of trauma (SAMHSA, 2014). The degree of traumatic stress that an individual experiences after traumatic circumstances or events depends upon many variables, such as the amount of control an individual has regarding the experience, the amount and type of supports available, the predictability of the events, and the degree of adaptability intrinsic to the individual (APA, 2013a).

The pervasive influence of trauma across the lifespan and its influence on affect regulation, attachment formation, and other medical, integrative, and developmental capacities are well documented (Briere, Kaltman, & Green, 2008; Feletti et al., 1998; Porges, 2008; Schore, 1994; van der Kolk, 2006). Some of the symptoms of individuals who have experienced multiple or prolonged trauma include difficulty with arousal regulation, re-experiencing of the traumatic stressors or events (e.g., nightmares, flashbacks), avoidance of trauma-related triggers, hypervigilance, dissociation, and being easily startled. These symptoms often result in difficulties with participating in meaningful life roles and activities. There is an abundance of research that has shown how trauma impacts the structure and function of the brain and why such trauma has a pervasive influence on an individual's life (De Bellis et al., 2002; De Bellis & Kuchibhatla, 2006).

Stewart and White (2008) revealed that people with PTSD have difficulty filtering out unwanted sensory stimuli, demonstrating patterns of SOR. Research also has shown that people with SOR, being more aware of sensory stimuli, have a higher risk and probability of developing PTSD if exposed to trauma (Hendler et al., 2003). Symptoms and behaviors seen in individuals with PTSD and in those with sensory processing problems may be viewed as adaptive responses, as these individuals may need to be able to identify risks and threats within the environment in order to protect themselves from potential danger. Hence, low sensory registration behaviors have been proposed as an example of a neurologically based, protective, adaptive response sometimes used to tune out or shut down the processing of sensory stimuli perceived as traumatic (Jerome & Liss, 2005). Through time, these nervous system responses may become dominating, habitual patterns that continue throughout adulthood when not addressed (Cloitre et al., 2009).

Using functional Magnetic Resonance Imaging (fMRI), Croy, Schellong, Joraschky, and Hummel (2010) examined how women with a history of childhood maltreatment process non-threatening and non-trauma-related olfactory stimuli as compared with control subjects. Individuals who had experienced childhood maltreatment showed enhanced activation in multiple, mainly neocortical, areas, such as the precentral frontal lobe, posterior parietal lobe, occipital lobe, and the posterior cingulate cortex. The results suggested there was a pattern of enhanced activation in associative and emotional brain regions. This indicates that following trauma, hypervigilance is often present, resulting in the central nervous system (CNS) being on constant alert. Because the CNS prioritizes the processing of danger and noxious sensory stimuli and is constantly assessing for threat(s), the individual's capacity to attend to other aspects of the environment is likely reduced. Research on trauma and stress reveals that these experiences often compromise one's ability to regulate, filter, organize, and process sensations (internal and external).

Mood Disorders

Mood disorders are the most common mental health disorders and include depressive disorders as well as bipolar disorder. Depression involves feelings of extreme sadness; being unmotivated; feeling worthless, helpless, or suicidal; and having little or no interest in typical pleasurable activities (APA, 2013a). People with depression also often have difficulties sleeping or eating. Bipolar disorder involves depressive episodes with periods of extreme excitement and irritability or mania. Symptoms of mania include feelings of extreme irritability; inflated self-esteem; and having racing thoughts, poor judgment, and the urge to engage in extremely risky behaviors (APA, 2013a). People with mood disorders often have difficulty successfully engaging in their daily occupations, such as completing tasks at work, managing a household, participating in leisure activities, and maintaining healthy relationships with family and friends.

Similar to what has been documented in individuals with schizophrenia, adults with bipolar disorder show electrophysiological deficits in the auditory domain and visual processing (Yeap et al., 2009). Auditory sensory gating is also problematic in individuals with bipolar disorder; for those with a history of psychosis sensory gating worsens (Cheng, Chan, Liu, & Hsu, 2016). Yeap and colleagues (2009) compared a sample of adults with bipolar disorder with age-matched healthy controls and, using electroencephalography, showed markedly different visual processing neurophysiology, suggestive of a dysfunction in visual processing. Lyoo and colleagues (2006) compared brain magnetic resonance images from a sample of subjects with and without bipolar disorder. They discovered that those with bipolar disorder exhibited significantly decreased cortical thickness in multiple prefrontal cortical areas and cortical thinning in sensory and sensory association cortices. These researchers concluded that such differences may account for some of the emotional, cognitive, and sensory processing impairments seen in adults with bipolar disorder. Newer research, using MRI technology to examine intracortical myelin in individuals with schizophrenia and those with bipolar disorder, found parallels between these disorders. Reduced intracortical myelin was identified in sensory and motor regions of the brain, leading investigators to hypothesize that inhibition of sensory input was reduced, leading to distortions in perceptual processing. Investigators emphasized that these results are preliminary (Jorgensen et al., 2016). Finally, the dysregulation of energy and arousal level that characterizes mood disorders appear quite similarly in individuals with sensory modulation disorders. Adults with depression may appear as having low levels of sensory registration or exhibit sensory-avoiding behaviors, whereas adults with mania appear as sensory seeking.

Evaluation and Intervention

The overwhelming evidence relating specific kinds of sensory processing dysfunction in adults with psychiatric or mental health disorders supports the application of SI theory and principles as part of comprehensive occupational therapy services in mental and behavioral health settings. Sensory-based assessments help to identify and describe some of the difficulties people with mental health disorders may have that significantly impact their ability to participate in their daily occupations. Assessment tools, such as the Adolescent/Adult SP (Brown & Dunn, 2002), the Adult/Adolescent Sensory History (May-Benson & Teasdale, 2015), Ayres' formal clinical observations, interviews focusing on detailed sensory histories, and informal observations of occupational performance (at home, community, work, or in the context of therapeutic groups), can provide valuable information about how sensory processing deficits are contributing to one's behavior, symptoms, and areas of occupational performance.

Among other intervention strategies, adults with mental health needs and goals can be taught to recognize their sensory differences and preferences and how they usually respond to certain sensory features of environments and activities.

This increased self-awareness can then be used to modify, reduce, or enhance the kinds of sensory input they experience on a daily basis to support their ability to function, increase comfort sensations, decrease undesirable or unsafe behaviors, and promote engagement in meaningful roles, routines, and occupations (Champagne & Frederick, 2011). The identification of individualized, sensory strategies to use as part of personal self-care plans, for grounding and self-soothing purposes, or mindfulness practice is often helpful with this population.

Sensory diets (see Chapter 18, Complementary Programs for Intervention, for more information) are routines that are collaboratively designed to ensure that individuals regularly and strategically schedule sensory-based activities that will help them self-regulate and perform to the best of their abilities throughout the day. The creation of predictable routines and adding structure to daily tasks also gives individuals more control regarding the amount and type of sensory input they experience. Personal safety plans can also be developed that include sensory-based strategies that are easily accessible to the individual (Chalmers, Harrison, Mollison, Molloy, & Gray, 2012).

Interventions for adults with mental health concerns largely focus on making environmental or activity modifications that consider sensory processing needs and preferences so that the person can more easily and successfully participate in his or her daily occupations. Environmental modifications might include setting up quiet, uncluttered work areas to minimize visual and auditory stimulation and eliminating fluorescent lighting. Simple highlighting or underlining of salient written instructions may assist in visually focusing, and tools such as day planners and personal electronic devices with reminders may assist with focus and organization. Sensory supportive spaces and portable sensory carts may be used in a variety of settings (e.g., home, residential, school, forensic) so that individuals can readily use and explore different stimuli as needed. Similar to therapeutic applications with youth, sensory approaches are also used to help individuals change their sensory processing patterns in order to support participation, and are not solely for coping, stress management, or regulatory purposes. Providing education and resources for individuals with mental illness and their family members regarding the symptoms and behaviors experienced, and how sensory processing abilities and challenges affect safety, behavior, and occupational participation, often provides a new and useful perspective.

Sensory-based interventions are provided as part of individual and group sessions. Chalmers and colleagues (2012) also researched the effectiveness of a group intervention for adults with mental illness, for improving awareness of the effects of different sensations on thoughts, behavior, and functioning. The sensory group provided an opportunity for clients to discuss, share, and explore their own sensory diets and preferences and to experiment with different sensory strategies (Chalmers et al., 2012). Finally, in some cases, more traditional sensory-based clinic interventions involving therapeutic activities or exercise that are heavily loaded with tactile, proprioceptive, and vestibular sensory input may be appropriate. Such interventions are best designed in accordance with the adult's specific sensory needs in mind and following the same basic principles of ASI, including being client-driven and incorporating challenging activities. Specific SI problems, such as dyspraxia, visual perceptual and visual motor deficits, sensory modulation challenges, or postural, praxis, and motor coordination problems, might be addressed using a more traditional ASI approach.

Chalmers and colleagues (2012) also looked at the effectiveness of various sensory strategies within one of their mental health facilities, including environment modifications, personal safety plans, sensory groups, a sensory room, and staff education on sensory-related issues. The results showed that 93% of patients believed the sensory room and the personal safety plans were most effective in stress reduction and for helping to control their symptoms. Sensory rooms were found to create a "safe space" within the unit where patients felt supported and comfortable. Similarly, the use of sensory strategies and creation of a sensory space for self-soothing purposes was shown to promote the ability to decrease agitation and better regulate autonomic arousal levels across four inpatient mental health units in New Zealand (Sutton, Wilson, Van Kessel, & Vanderpyl, 2013). Champagne and Stromberg (2004) had earlier demonstrated that staff training and the skilled use of a sensory modulation-style room with adults during an acute inpatient admission helped to reduce the use of seclusion and restraint by three standard deviations during the course of 1 year.

Sensory rooms are sometimes created in mental health-care and other types of settings serving adult populations, and they are geared primarily toward offering sensory strategies to promote self-nurturance, comfort, stress prevention, decreased patient distress or agitation, and for de-escalation of difficult behaviors (Chalmers et al., 2012; Champagne & Stromberg, 2004; Sutton et al., 2013; Wiglesworth & Farnworth, 2016). Sensory rooms are often described as being quiet spaces commonly found in an acute or long-term care mental health setting equipped with sensory modalities, such as massage chairs, beanbags, music, weighted blankets, light and visual features such as colored fish tanks, stress balls, water and fountain features, and lollipops or other candy (Chalmers et al., 2012; Champagne & Stromberg, 2004). Although there is limited research relative to their effectiveness, one recent study examining use of a sensory room in a forensic mental facility suggested that both staff and patients felt use of the room resulted in stress reduction (Wiglesworth & Farnworth, 2016).

Snoezelen™ rooms, often referred to as multisensory environments, are a type of sensory room that provides a variety of sensory experiences and that are generally used with individuals with moderate to severe cognitive impairments, such as dementia or psychosis. These rooms aim to promote relaxation and social interaction. Sensory rooms vary from setting to setting and can be tailored and modified to meet the needs of the clients they serve. Staff training is necessary to ensure the skilled and safe use of all items and equipment when creating and implementing the use of sensory rooms in different contexts.

Case Studies

Two case studies are presented in this section to demonstrate how occupational therapy using SI techniques may be applied to adults with mental health disorders. The first case, Janelle, is an adult with schizophrenia, and the second case describes a woman, Amy, with bipolar disorder.

CASE STUDY ▪ JANELLE

Janelle was a 28-year-old single mother diagnosed with schizophrenia, who was referred for occupational therapy at an outpatient community health clinic. During the initial interview, she reported that many sounds outside and groups of people made it hard for her to leave the house. She reported feeling uncomfortable running errands, such as going grocery shopping, attending groups at her day program, and going to meetings or events at her daughter's school. She stated that, "I no longer go out of the house much, and I do not spend time with any of my friends." She also reported discomfort with intimate relationships and with completing some self-care, home maintenance, and child-care tasks. She reported that she often did not feel comfortable in her own skin and found it difficult to navigate in the environment because of a fear of elevators, escalators, and even going up and down stairs. She stated that she bumps into things and falls down easily. She also reported that she struggles with symptoms of schizophrenia, including feelings of paranoia and experiencing hallucinations.

As part of the evaluation process, the occupational therapist helped Janelle identify her strengths and challenges, what was most important to her, and what she wanted to work on. Assessment tools, in addition to the interview, included the QNST-3 (Mutti et al., 1999), Clinical Observations of Sensory Integration (Blanche, 2002), Adolescent/Adult SP (Brown & Dunn, 2002), and the Sensory Modulation Screening Tool (Champagne, 2011b). Janelle's assessment results were consistent with the types of sensory processing concerns that she shared during the initial interview. Her sensory processing suggested sensory modulation concerns, with scores much higher than others in low registration, sensory sensitivity, and avoiding patterns. Sensory discrimination problems, including somatosensory, auditory, and visual discrimination challenges, were identified, as well as a sensory-based motor disorder characterized by low muscle tone, poor bilateral coordination, and poor praxis or motor planning skills. The therapist and Janelle discussed how Janelle's sensory processing challenges were impacting her ability to carry out her daily occupations and contributing to her feelings of discomfort in her own skin and when going outside the home. Intervention goals were developed collaboratively with Janelle, who wanted to address her sensory modulation problems, difficulty with balance and visual-spatial perception, and fine and gross motor coordination as she felt these were barriers to recovery and to successful occupational participation.

Janelle was interested in using some of the equipment in the occupational therapy gym, such as suspended equipment to address balance, coordination, and motor planning. Visual tracking and aiming activities were also incorporated; she sometimes planned, set up, and completed physical challenge obstacle courses that involved climbing and balancing activities, and she did some arts and crafts activities using a variety of different textured materials and media. Janelle was taught how to carry over the skills she was learning in the clinic at home and how she could incorporate some of the activities she was doing in the clinic space into her daily routines. A home program was created with the support of her outreach worker and included the use of graded activities of daily living and leisure activities. She created a sensory kit (Fig. 19-16) where she kept some sensory tools organized and readily available for use as part of a sensory diet to prevent her from becoming overstimulated or agitated or for calming when necessary. She modified a corner in her bedroom and living room where she could use sensory modulation strategies as needed, and she used a daily self-rating scale to monitor her behavior and to track her progress.

After 6 months of weekly occupational therapy services and follow through with her home program, Janelle demonstrated significant gains. The skills that she had learned helped her perform more competently and comfortably the everyday self-care, child care, leisure, and home management activities that she wanted, and was expected, to do. She increased her participation in meaningful life roles (e.g., parent, friend, day program participant), and, through time, she began to feel more comfortable going out into the community. For example, she signed herself and her daughter up for swimming lessons at the local YMCA, she enrolled in a small yoga class, and she more regularly took her daughter to a park with a playground.

FIGURE 19-16 Janelle developed a kit with sensory tools to support strategies she used as part of her sensory diet. *Photo courtesy of Carissa Reinbein.*

CASE STUDY ■ AMY

Amy was a graduate student completing her final school counseling internship at her local high school. She had been diagnosed with bipolar disorder in her freshman year of college. Amy self-referred for an occupational therapy evaluation after learning about SI from the occupational therapist at her internship site. Amy reported that she always knew she was different and could never understand why so many things bothered her that did not bother others. She remembered feeling this way from a very young age.

Amy was evaluated using an interview, and the QNST-3 (Mutti et al., 1999) and Adolescent/Adult SP (Brown & Dunn, 2002) were administered. She reported her primary concerns as her ability to complete her internship successfully and maintain successful employment in a school setting as a school counselor. She reported feeling traumatized in her internship environment every day, as she was overwhelmed by the amount and intensity of sensory stimuli at work. Results of the evaluation revealed moderate tactile hypersensitivity, impacting the types of clothing she would wear and causing feelings of discomfort with unexpected touch from others. She described feeling pain when wearing certain types of work clothes and also having intense feelings of wanting to hit people throughout the day when they bumped into her in the halls or came up from behind and touched her. The noise of the school environment was overwhelming her, and she had difficulty interacting with others in many of the classrooms because of the noise and brightness of the fluorescent lighting. She reported that she very much enjoyed working with the students and her colleagues but that she often left work with headaches and completely exhausted. Previously she had been able to cope with her sensory differences by avoiding stimulating environments or by making sure that activities and environments were at least predictable for her. However, these coping strategies were not effective in her new work environment. Amy reported that as a child she was clumsy and had a difficult time keeping up with her peers in motor activities. However, this was no longer a concern because the activities she chose to participate in now suited her motor skills.

Intervention began with providing education on SI and processing so Amy could better understand her own behaviors and feelings. This knowledge helped her become more self-aware regarding how her sensory issues impacted her participation and performance throughout her daily activities. Although she was unable to make adaptations to her school environment to decrease the amount of sensory stimuli in the classrooms or hallways, she did have an office area where she could make adaptations to minimize the noise and lighting. The therapist also suggested that she retreat to her office for short time periods during the day in order to implement activities that provided modulating sensory input and to recuperate after being in very stimulating environments. Together with her therapist, she identified activities that provided deep pressure as well as tactile, proprioceptive, and calming vestibular sensory input for implementation throughout her daily routines. Some of these included a rigorous hike before work in the morning (Fig. 19-17) and doing a short yoga workout in the school gym during her lunchtime, which also allowed her to avoid the school cafeteria area. She used a weighted lap beanbag or did chair pushups when sitting at her desk, which provided deep pressure and proprioceptive input. As Amy developed a better understanding of SI, she expanded the types and amounts of modulating sensory activities both at home and in the school environment. For instance, she began practicing yoga at home as a way of lowering her arousal level at the end of the day (Fig. 19-18). Intervention was discontinued

FIGURE 19-17 Amy began engaging in morning hikes whenever possible, providing proprioception, tactile, and vestibular inputs, to prepare for the day ahead. *Photo courtesy of Melissa Tucker.*

FIGURE 19-18 Amy used yoga at home, providing her with proprioceptive input, to reduce stress at the end of the day. *Photo courtesy of Melissa Tucker.*

after six weekly sessions that were collaborative and more consultative in nature. Amy did well with intervention and was happy to report to her therapist that she not only successfully completed her internship but that she was hired on as a school counselor at the school.

HERE'S THE POINT

- There is a solid research base linking SI and processing problems with many mental disorders.
- Common sensory-based approaches include providing activity and environmental modifications, providing education on how sensory processing differences associated with certain mental disorders impact one's behavior and functioning, use of sensory rooms, developing and implementing sensory diets, and providing traditional ASI.

Where Can I Find More?

Bar-Shalita, T., & Cermak, S. A. (2016). Atypical sensory modulation and psychological distress in the general population. *American Journal of Occupational Therapy, 70,* 1–9.

Bar-Shalita, T., Vatine, J., Parush, S., Deutsch, L., & Seltzer, Z. (2012). Psychophysical correlates in adults with sensory modulation disorder. *Disability and Rehabilitation, 34*(11), 943–950.

Ben-Avi, N., Almagor, M., & Engel-Yeger, B. (2012). Sensory processing difficulties and interpersonal relationships in adults: An exploratory study. *Psychology, 3,* 70–77.

Champagne, T. (2011c). The influence of posttraumatic stress disorder, depression, and sensory processing patterns on occupational engagement: A case study. *WORK: A Journal of Prevention, Assessment, & Rehabilitation, 38*(1), 67–75.

Summary and Conclusions

In Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited), we indicated that there were boundaries in the application of SI theory. More importantly, we indicated that when therapists work outside the boundaries of the initial theory, they must proceed with caution. The sections in this chapter reflect the cautious thinking of therapists and experts on the application of theoretical constructs outside these original boundaries. Bigsby provides support for the application of sensory integrative theory and practice for high-risk infants, and she indicates that applying these ideas as part of a family-centered intervention approach is important. Considering childhood disorders, Mulligan, as well as Benevides and colleagues, indicated that both ADHD and ASD have a more substantive history of disorders in modulation and praxis, and there is increasing support for the use of a sensory integrative approach as a component of intervention. An additional application of sensory integrative constructs is described by Kennedy, relative to disorders of trauma and attachment, where increasingly we are seeing references to difficulties with sensory processing as part of the overall concerns. She further explained that blending a sensory integrative foundation with an approach that emphasizes regulation and relationship building is showing promise for TIC. Pfeiffer indicated that adults with and without other diagnoses can be identified as having disorders of sensory modulation, and that a consultative approach to treatment is useful in supporting occupational participation. Expanding on this, Champagne and Pfeiffer stated that individuals with mental health disorders, across the age spectrum, also experience disorders of SI, suggesting that intervention should give consideration to the use of SI constructs. Each of these sections was carefully considered and supported by available research. Thus, increasingly there is a research basis for expanding the original boundaries of SI theory and practice. However, as has been stated in other chapters in this book, more research is needed.

References

Als, H. (1982). Toward a synactive theory of development: Promise for the assessment and support of infant individuality. *Infant Mental Health Journal, 3,* 229–243.

Als, H., Duffy, F. H., McAnulty, G. B., Rivkin, M. J., Vajapeyam, S., Mulkern, R. V., . . . Eichenwald, E. C. (2004). Early experience alters brain function and structure. *Pediatrics, 113,* 4, 846–856.

Altimier, L., Kenner, C., & Damus, K. (2015). Developmental care of premature neonates. *Newborn and Infant Nursing Reviews, 15,* 6–16. doi:10.1053/j.nainr.2015.01.006

American Academy of Pediatrics. (2011). ADHD: Clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Pediatrics, 128*(5), 1–16.

American Psychiatric Association. (2013a). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

American Psychiatric Association. (2013b). Neurodevelopmental disorders. In *Diagnostic and statistical manual of mental disorders* (5th ed.), pp. 31–86. Arlington, VA: American Psychiatric Publishing. doi:10.1176/appi.books.9780890425596.514988

Arnfred, S., & Chen, A. (2004). Exploration of somatosensory P50 gating in schizophrenia spectrum patients: Reduced P50 amplitude correlates to social anhedonia. *Psychiatry Research, 125,* 147–160.

Ashburner, J., Rodger, S., Ziviani, J., & Jones, J. (2014). Occupational therapy services for people with autism spectrum disorders: Current state of play, use of evidence, and future learning priorities. *Australian Occupational Therapy Journal, 61,* 110–120. doi:10.1111/1440-1630.12083

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American Journal of Occupational Therapy, 62*(5), 564–573.

Atanasova, B., Graux, J., El Hage, W., Hommet, C., Camus, V., & Belzung, C. (2008). Olfaction: A potential cognitive marker of psychiatric disorders. *Neuroscience Biobehavioral Review, 32,* 1315–1325.

Aton, S. J. (2013). Set and setting: How behavioral state regulates sensory function and plasticity. *Neurobiology, Learning and Memory, 106,* 1–10.

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1975). *Sensory integration and learning disorders* (4th ed.). Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1979). *Sensory integration and the child*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests, revised manual*. Torrance, CA: Western Psychological Services.

Ayres, A. J. (2005). *Sensory integration and the child, 25th anniversary edition*. Los Angeles, CA: Western Psychological Services.

Bailey, D. B., Hebbeler, K., Spiker, D., Scarborough, A., Mallik, S., & Nelson, L. (2005). Thirty-six-month outcomes for families of children who have disabilities and participated in early intervention. *Pediatrics, 116,* 1346–1352.

Bakker, K., & Moulding, R. (2012). Sensory-Processing Sensitivity, dispositional mindfulness and negative psychological symptoms. *Personality and Individual Differences, 53,* 341–356.

Balaban, C. (2002). Neural substrates linking balance control and anxiety. *Physiology & Behavior, 77*(4-5), 469–475.

Balaban, C. D., & Jacob, R. G. (2001). Background and history of the interface between anxiety and vertigo. *Journal of Anxiety Disorders, 15,* 27–51.

Baranek, G. T. (2002). Efficacy of sensory and motor interventions for children with autism. *Journal of Autism and Developmental Disorders, 32*(5), 397–422.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory experiences questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 47*(6), 591–601.

Baum, C. M., Connor, L. T., Morrison, T., Hahn, M., Dromerick, A. W., & Edwards, D. F. (2008). Reliability, validity, and clinical utility of the Executive Function Performance Test: A measure of executive function in a sample of people with stroke. *American Journal of Occupational Therapy, 62,* 446–455.

Bayley, N. (2005). *Bayley Scales of Infant and Toddler Development* (3rd ed.). San Antonio, TX: Pearson Education.

Beck, A. T., & Steer, R. A. (1987). Manual for the *Beck Depression Inventory*. San Antonio, TX: Psychological Corporation.

Beck, A. T., & Steer, R. A. (1990). Manual for the *Beck Anxiety Inventory*. San Antonio, TX: Psychological Corporation.

Ben-Avi, N., Almagor, M., & Engel-Yeger, B. (2012). Sensory processing difficulties and interpersonal relationships in adults: An exploratory study. *Psychology, 3,* 70–77.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(1), 1–11.

Bhat, A. N., Landa, R. J., & Galloway, J. C. (2011). Current perspectives on motor functioning in infants, children and adults with autism spectrum disorders. *Physical Therapy, 91,* 1116–1129. doi:10.2522/ptj.20100294

Blanche, E. I. (2002). *Observations based on sensory integration theory*. Torrance, CA: Pediatric Therapy Network.

Boundy, E.O., Dastierdi, R., Spiegelman, D., Fawzo, W.W., Missmer, S.A., Lieberman, E., … Chan, G.J. (2016). Kangaroo mother care and neonatal outcomes: A meta-analysis. *Pediatrics*, *137* (1) (no pagination). doi:10.1542/peds.2015-2238

Bowlby, J. (1988). *A secure base: Parent-child attachment and healthy human development*. London, England: Routledge.

Briere, J., Kaltman, S., & Green, B. (2008). Accumulated childhood trauma and symptom complexity. *Journal of Traumatic Stress, 21,* 223–226.

Bröring, T., Oostrom, K. J., Lafeber, H. N., Jansma, E. P., & Oosterlaan, J. (2017). Sensory modulation in preterm children: Theoretical perspective and systematic review. *PLOS ONE, 12*(2), e0170828. doi:10.1371/journal.pone.0170828

Brown, C. (2014). Ecological models in occupational therapy. In B. A. Boyt Schell, G. Gillen, & M. E. Scaffa (Eds.), *Willard & Spackman's occupational therapy* (12th ed., pp. 494–504). Philadelphia, PA: Lippincott Williams & Wilkens.

Brown, C., Cromwell, R. L., Filion, D., Dunn, W., & Tollefson, N. (2002). Sensory processing in schizophrenia: Missing and avoiding information. *Schizophrenia Research, 55,* 187–195. doi:10.1016/S0920-9964(01)00255-9

Brown, C., & Dunn, W. (2002). *Adolescent/Adult Sensory Profile*. Hudson, NY: Pearson Assessment.

Butler, P. D., Abeles, I. Y., Weiskopf, N. G., Tambini, A., Jalbrzikowski, M., Legatt, M. E., . . . Javitt, D. C. (2009). Sensory contributions to impaired emotional processing in schizophrenia. *Schizophrenia Bulletin, 35,* 1095–1107.

Butler, P. D., Martinez, A., Foxe, J. J., Kim, D., Zemon, V., Silipo, G., . . . Javitt, D. (2007). Subcortical visual dysfunction in schizophrenia drives secondary cortical impairments. *Brain, 130*(2), 417–430.

Butler, P. D., Zemon, V., Schechter, I., Saperstein, A., Hoptman, M., Lim, K., . . . Javitt, D. (2005). Early-stage visual processing and cortical amplification deficits in schizophrenia. *Archives General Psychiatry, 62,* 495–504.

Case-Smith, J., Weaver, L. L., & Fristad, M. A. (2014). A systematic review of sensory processing interventions for children with autism spectrum disorders. *Autism, 19*(2), 133–148. doi:10.1177/1362361313517762

Centers for Disease Control and Prevention. (2014). Prevalence of autism spectrum disorder among children aged 8 years—autism and developmental disabilities monitoring network, 11 sites, United States, 2010. *Morbidity and Mortality Weekly Report, 63*(SS02), 1–21.

Cermak, S., & Maeir, A. (2011). Cognitive rehabilitation of children and adults with attention deficit hyperactivity disorder. In N. Katz (Ed.), *Cognition, occupation, and participation across the lifespan* (3rd ed., pp. 249–276). Bethesda, MD: AOTA Press.

Chalmers, A., Harrison, S., Mollison, K., Molloy, K., & Gray, K. (2012). Establishing sensory-based approaches in mental health inpatient care: A multidisciplinary approach. *Australian Psychiatry, 20,* 35–39.

Champagne, T. (2011a). Attachment, trauma, and occupational therapy practice. *OT Practice, 16*(5), CE1–8.

Champagne, T. (2011b). *Sensory modulation & environment: Essential elements of occupation* (3rd ed. Rev.). Sydney, Australia: Pearson Assessment.

Champagne, T. (2011c). The influence of posttraumatic stress disorder, depression, and sensory processing patterns on occupational engagement: A case study. *WORK: A Journal of Prevention, Assessment, & Rehabilitation, 38*(1), 67–75.

Champagne, T., & Frederick, D. (2011). Sensory processing research advances in mental health: Implications for occupational therapy. *OT Practice, 10,* 7–12.

Champagne, T., & Stromberg, N. (2004). Sensory approaches in inpatient psychiatric settings: innovative alternatives to seclusion and restraint. *Journal of Psychosocial Nursing*, *42*(9), 1–8.

Chang, B. P., & Lenzenweger, M. F. (2005). Somatosensory processing and schizophrenia liability: Proprioception, exteroceptive sensitivity, and graphesthesia performance in the biological relatives of schizophrenia patients. *Journal of Abnormal Psychology, 114,* 85–95.

Charpak, N., Tessier, R., Ruiz, J. G., Hernandez, J. T., Uriza, F., Villegas, J., . . . Maldonado, D. (2017). Twenty-year follow-up of kangaroo mother care versus traditional care. *Pediatrics, 139*(1), 1–10.

Chen, Y. (2011). Abnormal visual motion processing in schizophrenia: A review of research progress. *Schizophrenia Bulletin, 37,* 709–715.

Cheng, C. H., Chan, P. Y., Liu, C. Y., & Hsu, S. C. (2016). Auditory sensory gating in patients with bipolar disorders: A meta-analysis. *Journal of Affect Disorders, 203,* 199–203.

Chorna, O., Solomon, J. E., Slaughter, J. C., Strak, A. R., & Maitre, N. L. (2014). Abnormal sensory reactivity in preterm infants during the first year correlates with adverse neurodevelopmental outcomes at 2 years of age. *Archives of Diseases in Childhood, Fetal Neonatal Edition, 99,* 475–479.

Cloitre, M., Stolbach, B. C., Herman, J. L., van der Kolk, B., Pynoos, R., Wang, J., & Petkova, E. (2009). A developmental approach to complex PTSD: Childhood and adult cumulative trauma as predictors of symptom complexity. *Journal of Traumatic Stress, 22,* 399–408.

Cohn, J. F., & Tronick, E. Z. (1987). Mother-infant face to face interaction: The sequence of dyadic states. *Developmental Psychology, 23,* 1, 68–77.

Collins, A., & Dworkin, R. J. (2011). Pilot study of the effectiveness of weighted vests. *American Journal of Occupational Therapy, 65*(6), 688–694. doi:10.5014/ajot.2011.000596

Conde-Agudelo, A., & Diaz-Rossello, J. L. (2016). Kangaroo mother care to reduce morbidity and mortality in low birthweight infants. *Cochrane Database Systematic Reviews,* 8, Art. No. CD002771. doi:10.1002/1465858.CD002771 .pub4

Conners, C. K. (2008). *Conners' manual* (3rd ed.). Toronto, Ontario, Canada: Multi-Health Systems Inc.

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. *Autism, 13,* 215–228.

Croy, I., Schellong, J., Joraschky, P., & Hummel, T. (2010). PTSD, but not childhood maltreatment, modifies responses to unpleasant odors. *International Journal of Psychophysiology, 75,* 326–331.

Davidson, J. (2010). 'It cuts both ways': A relational approach to access and accommodation for autism. *Social Science & Medicine, 70,* 305–312.

Davis, T. N., Durand, S., & Chan, J. M. (2011). The effects of a brushing procedure on stereotypical behavior. *Research in Autism Spectrum Disorders, 5*(3), 1053–1058. doi:proxy1.lib.tju.edu/10.1016/j.rasd.2010.11.011

Dawson, G., & Bernier, R. (2013). A quarter century of progress on the early detection and treatment of autism spectrum disorder. *Development and Psychopathology, 25*(4pt2), 1455–1472. doi:10.1017/S0954579413000710

Dawson, G., & Watling, R. (2000). Interventions to facilitate auditory, visual, and motor integration in autism: A review of the evidence. *Journal of Autism and Developmental Disabilities, 30*(5), 415–421.

De Bellis, M. D., Keshavan, M. S., Frustaci, K., Shifflett, H., Iyengar, S., Beers, S. R., & Hall, J. (2002). Superior temporal gyrus volumes in maltreated children and adolescents with PTSD. *Biological Psychiatry, 51,* 544–552.

De Bellis, M. D., & Kuchibhatla, M. (2006). Cerebellar volumes in pediatric maltreatment-related posttraumatic stress disorder. *Biological Psychiatry, 60,* 697–703.

DeGangi, G., & Greenspan, S. (1989). *Test of Sensory Function in Infants*. Torrance, CA: Western Psychological Services.

DeSousa, A., & Kalra, G. (2012). Drug therapy of attention deficit hyperactivity disorder: Current trends. *Mens Sana Monograph, 10*(1), 45–69.

Dunn, W. (1999). *Sensory Profile*. San Antonio, TX: Pearson, PsychCorp.

Dunn, W. (2002). *Infant/Toddler Sensory Profile*. Austin, TX: Pearson.

Dunn, W. (2014). *Sensory Profile-2*. Austin, TX: Pearson.

Dunn, W., & Bennett, D. (2002). Patterns of sensory processing in children with attention deficit hyperactivity disorder. *Occupational Therapy Journal of Research, 22,* 4–5. doi:10.1177/153944920202200102

Dunn, W., & Daniels, D. (2002). *Infant/Toddler Sensory Profile*. Hudson, NY: Pearson Assessment.

Dunst, C. J., Bruder, M. B., & Espe-Shervindt, M. (2014). Family capacity building in early childhood intervention: Do context and setting matter? *School Community Journal, 24,* 1, 37–48.

Egeland, J., Ueland, T., & Johansen, S. (2012). Central processing energetic factors mediate impaired motor control in ADHD combined subtype but not in ADHD inattentive subtype. *Journal of Learning Disabilities, 45*(4), 361–370. doi:10.1177/0022219411407922

Engel-Yeger, B., & Dunn, W. (2011). The relationship between sensory processing difficulties and anxiety levels of healthy adults. *British Journal of Occupational Therapy, 74,* 210–216.

Fedewa, A. L., & Erwin, H. E. (2011). Stability balls and students with attention and hyperactivity concerns: Implications for on-task and in-seat behavior. *American Journal of Occupational Therapy, 65*(4), 393–399. doi:10.5014/ajot.2011.000554

Feldman, R., Rosenthal, Z., & Eidelman, A. (2014). Maternal-preterm skin-to-skin contact enhances child physiologic organization and cognitive control across the first 10 years of life. *Biological Psychiatry, 75*(1), 56–64.

Feletti, V., Anda, R., Nordenberg, D., Williamson, D., Spitz, A., Edwards, V., . . . Marks, J. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults. The adverse childhood experiences study. *American Journal of Preventative Medicine, 14*(4), 245–258.

Fertel-Daly, D., Bedell, G., & Hinojosa, J. (2001). Effects of a weighted vest on attention to task and self-stimulatory behaviors in preschoolers with pervasive developmental disorders. *American Journal of Occupational Therapy, 55*(6), 629–640.

Gillberg, C. (2003). Deficits in attention, motor control, and perception: A brief review. *Archives of Disability in Children, 88,* 904–910. doi:10.1136/adc.88.10.904

Giolo, G. A., Isquith, P. K., Guy, S., & Kenworthy, L. (2000). *Brief Rating Inventory of Executive Functions (BRIEF)*. Lutz, FL: Psychological Assessment Resources.

Golden, C. J., & Freshwater, S. M. (2002). *Stroop color and word test*. Torrance, CA: Western Psychological Services.

Haith, M. M. (1991). Setting a path for the '90s: Some goals and challenges—Infant sensory and perceptual development. Paper. Meetings of the Society for Research in Child Development, Seattle, WA.

Harrison, P. L., & Oakland, T. (2003). *Adaptive Behavior Assessment Systems, Second Edition* (ABAS-II). San Antonio, TX: PsychCorp.

Hellgren, L., Gillberg, I. C., Bagenholm, A., & Gilberg, C. (1994). Children with deficits in attention, motor control, and perception (DAMP) almost grown up: Psychiatric and personality disorders at age 16. *Journal of Child Psychology and Psychiatry, 35,* 1255–1271. doi:10.1111/j.1469-7610.1994.tb01233.x

Hendler, T., Rotshtein, P., Yeshurun, Y., Weizman, T., Kahn, I., Ben-Bashat, D., & Bleich, A. (2003). Sensing the invisible: Differential sensitivity of

visual cortex and amygdala to traumatic context. *Neuroimage, 19,* 587–600.
Hendriksen, H., Prins, J., Olivier, B., & Oosting, R. S. (2010). Environmental enrichment induces behavioral recovery and enhanced hippocampal cell proliferation in an antidepressant-resistant animal model for PTSD. *PLOS ONE, 5,* e11943. doi:10.1371/journal.pone.0011943
Hoffman, S., & Bitran, S. (2007). Sensory processing sensitivity in social anxiety disorder: Relationship to harm avoidance and diagnostic subtypes. *Journal of Anxiety Disorders, 21,* 944–954.
Holditch-Davis, D., & Thoman, E. (1987). Behavioral states of premature infants: Implications for neural and behavioral development. *Developmental Psychology, 20,* 1, 25–38.
Holmberg, K., Sundelin, C., & Hjern, A. (2013). Screening for attention deficit hyperactivity disorder (ADHD): Can high risk children be identified in first grade? *Child Care Health and Development, 39*(2), 268–276.
Iwanaga, R., Honda, S., Nakane, H., Tanaka, K., Toeda, H., & Tanaka, G. (2013). Pilot study: Efficacy of sensory integration therapy for Japanese children with high-functioning autism spectrum disorder. *Occupational Therapy International*, *21*(1), 4–11. doi:10.1002/oti.1357
Jacob, R., Whitney, S., Detweiler-Shostak, G., & Furman, J. (2001). Vestibular rehabilitation for patients with agoraphobia and vestibular dysfunction: A pilot study. *Anxiety Disorder, 15,* 131–146.
Jahshan, C. C., Cadenhead, K. S., Rissling, A. J., Kirihara, K. K., Braff, D. L., & Light, G. A. (2012). Automatic sensory information processing abnormalities across the illness course of schizophrenia. *Psychological Medicine, 42*(1), 85–97. doi:10.1017/S0033291711001061
Javitt, D. C. (2009a). Sensory processing in schizophrenia: Neither simple nor intact. *Schizophrenia Bulletin, 35,* 1059–1064.
Javitt, D. C. (2009b). When doors of perception close: Bottom-up models of disrupted cognition in schizophrenia. *Annual Review of Clinical Psychology, 5,* 249–275.
Jerome, E. M., & Liss, M. (2005). Relationships between sensory processing style, adult attachment, and coping**.** *Personality and Individual Differences, 38,* 1341–1352.
Jorgensen, K. N., Nerland, S., Norbom, L. B., Doan, N. T., Nesvag, L., Morch-Jonse, L., . . . Agartz, I. (2016). Increased MRI-based cortical grey/white-matter contrast in sensory and motor regions in schizophrenia and bipolar disorder. *Psychological Medicine, 46*(9), 1971–1985.
Kaffman, A., & Meaney, M. J. (2007). Neurodevelopmental sequelae of postnatal maternal care in rodents: Clinical and research implications of molecular insights. *Journal of Child Psychology and Psychiatry, 48,* 224–244. doi:10.1111/j.1469-7610.2007.01730.x
Kantrowitz, J., Butler, P. D., Schecter, I., Silipo, G., & Javitt, D. C. (2009). Seeing the world dimly: The impact of early visual deficits on visual experience in schizophrenia. *Schizophrenia Bulletin, 35,* 1085–1094.
Kaplan, B., Crawford, S., Cantell, M., Kooistra, L., & Dewey, D. (2006). Co-morbidity, co-occurrence, continuum: What's in a name? *Child Care, Health and Development, 32*(6), 723–731.
Karen, R. (1998). *Becoming attached*. New York, NY: Oxford University Press.
Katz, N., Parush, S., & Traub Bar-Ilan, R. (2004). Dynamic Occupational Therapy Cognitive Assessment for Children (DOTCA-Ch). Framington, MA: Therapro Inc.
Keil, J., Roa Romero, Y., Balz, J., Henjes, M., & Senkowski, D. (2016). Positive and negative symptoms in schizophrenia relate to distinct oscillatory signature of sensory gating. *Frontiers in Human Neuroscience, 10,* Article 104. doi:10.3389/fnhum.2016.00104
Kim, D., Wylie, G., Pasternak, R., Butler, P. D., & Javitt, D. C. (2006). Magnocellular contributions to impaired motion processing in schizophrenia. *Schizophrenia Research, 82,* 1–8.
Kim, T. I., Shin, Y. H., & White-Traut, R. C. (2003). Multisensory intervention improves physical growth and illness rates in Korean orphaned newborn infants. *Research in Nursing & Health, 26,* 424–433. doi:10.1002/nur.10105
Kimball, J. G., Lynch, K. M., Stewart, K. C., Williams, N. E., Thomas, M. A., & Atwood, K. D. (2007). Using salivary cortisol to measure the effects of a Wilbarger protocol-based procedure on sympathetic arousal: A pilot study. *American Journal of Occupational Therapy, 61*(4), 406–413.
Kinnealey, M., & Fuiek, M. (1999). The relationship between sensory defensiveness, anxiety, depression and perception of pain in adults. *Occupational Therapy International, 6,* 195–206.
Kinnealey, M., Koenig, K. P., & Smith, S. (2011). Relationships between sensory modulation and social supports and health-related quality of life. *American Journal of Occupational Therapy, 65,* 320–327.
Kinnealey, M., & Oliver, B. (1999). *Adult Defensiveness, Understanding, Learning, Teaching: Sensory Interview (ADULT-SI).* Unpublished document.
Kinnealey, M., Oliver, B., & Wilbarger, P. (1995). A phenomenological study of sensory defensiveness in adults. *American Journal of Occupational Therapy, 49*(5), 444–451.
Kinnealey, M., & Smith, S. (2002). Sensory defensive and non-defensive adults: Physiological and behavioral differences. Presented at the World Federation of Occupational Therapy Conference, in Stockholm, Sweden.
Kiresuk, T. J., Smith, A., & Cardillo, J. E. (1994). *Goal attainment scaling: Applications, theory and measurement*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Koomar, J. A. (2009, December). Trauma- and attachment-informed sensory integration assessment and intervention. *Sensory Integration Special Interest Section Quarterly, 32*(4), 1–4.

Koomar, J. A. (2012, April). Examination of qualitative and quantitative aspects of sensory processing in adults. Paper presented at the American Occupational Therapy Association Annual Conference & Expo, Indianapolis, Indiana.

Kuyper, L. M. (2011). *The Zones of Regulation: A curriculum designed to foster self-regulation and emotional control*. San Jose, CA: Think Social Publishing, Inc.

Lane, A. E., Young, R. L., Baker, A. E., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism and Developmental Disorders, 40*(1), 112–122.

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience, 4*. doi:10.3389/fnint.2010.00008

Law, M., Baptiste, S., Carswell, A., McColl, M., Polatajko, H., & Pollack, N. (2005). *Canadian Occupational Performance Measure* (4th ed.). Ottawa, Ontario: CAOT Publications.

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders, 37,* 894–910. doi:10.1007/s10803-006-0218-7

Leitman, D. I., Foxe, J. J., Butler, P. D., Saperstein, A., Revheim, N., & Javitt, D. C. (2005). Sensory contributions to impaired prosodic processing in schizophrenia. *Biological Psychiatry, 58,* 56–61.

Leitman, D. I., Laukka, P., Juslin, P. N., Saccente, E., Butler, P., & Javitt, D. C. (2008). Getting the cue: Sensory contributions to auditory emotion recognition impairments in schizophrenia. *Schizophrenia Bulletin, 36,* 545–556.

Lester, B. M., Hawes, K., Abar, B., Sullivan, M., Miller, R., Bigsby, R., . . . Padbury, J. F. (2014). Single-family room care improves neurobehavioral and medical outcomes in preterm infants. *Pediatrics, 134,* 4, 754–760.

Lester, B. M., Salisbury, A. L., Hawes, K., Danserau, L. M., Bigsby, R., Laptook, A., . . . Padbury, J. F. (2016). 18-Month follow-up of infants cared for in a single-family room neonatal intensive care unit. *Journal of Pediatrics, 177,* 84–90.

Liaw, J. J., Yang, L., Lee, C. M., Fan, H. C., Chang, Y. C., & Cheng, L. P. (2013). Effects of combined use of non-nutritive sucking, oral sucrose, and facilitated tucking on infant behavioral states across heel-stick procedures: A prospective, randomized controlled trial. *International Journal of Nursing Studies*, *50,* 7, 883–894.

Lickliter, R. (2011). The integrated development of sensory organization. *Clinics in Perinatology, 38,* 4, 591–603.

Lin, H.-Y., Lee, P., Chang, W.-D., & Hong, F.-Y. (2014). Effects of weighted vests on attention, impulse control, and on-task behavior in children with attention deficit hyperactivity disorder. *American Journal of Occupational Therapy, 68*(2), 149–158. doi:10.5014/ajot.2014.009365

Linderman, T. M., & Stewart, K. B. (1999). Sensory integrative-based occupational therapy and functional outcomes in young children with pervasive developmental disorders: A single-subject study. *American Journal of Occupational Therapy, 53*(2), 207–213.

Liss, M., Timmel, L. J., Baxley, K., & Killingsworth, P. (2005). Sensory processing sensitivity and its relationship to parental bonding, anxiety and depression. *Personality and Individual Differences, 39,* 1429–1439.

Ludewig, S., Geyer, M., Ramseier, M., Vollenweider, F., Rechsteiner, E., & Cattapan-Ludewig, K. (2005). Information-processing deficits and cognitive dysfunction in panic disorder. *Journal of Psychiatry & Neuroscience, 30*(1), 37–43.

Lyoo, I., Sung, Y., Dager, S. R., Friedman, S. D., Lee, J., Kim, S., . . . Renshaw, P. F. (2006). Regional cerebral cortical thinning in bipolar disorder. *Bipolar Disorders, 8*(1), 65–74. doi:10.1111/j.1399-5618.2006.00284.x

Mangeot, S. D., Miller, L. J., McIntosh, D. N., McGrath-Clarke, J., Simon, J., Hagerman, R. J., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit–hyperactivity disorder. *Developmental Medicine & Child Neurology, 43*(06), 399–406. doi:10.1111/j.1469-8749.2001.tb00228.x

Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1998). *Test of Everyday Attention for Children, The TEA-Ch*. San Antonio, TX: PsychCorp.

May-Benson, T., & Kinnealey, M. (2002, September). An approach to assessment of intervention for adults with sensory processing disorders. *OT Practice, 17*(17), CE-1–CE-8.

May-Benson, T., & Koomar, J. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy, 64,* 403–414.

May-Benson, T., & Patane, S. (2010). *Commonalities in sensory processing of adults seeking sensory integration-based occupational therapy services: A qualitative analysis*. Watertown, MA: The Spiral Foundation.

May-Benson, T., & Teasdale, A. (2015). Concurrent Validity of the Adult/Adolescent Sensory History (ASH). *American Journal of Occupational Therapy*, *69,* 6911500193p1. doi:10.5014/ajot.2015.69S1-PO6097

Micoulaud-Franchi, J. A., Faugere, M., Boyer, L., Cermolacce, M., Fond, G., Richieri, R., …Lancon, C. (2016). Sensory gating deficits and impaired quality of life in patients with schizophrenia: A preliminary study. *Psychiatria Danubina, 28*(3), 225–233.

Milgrom, J., Newnham, C., Anderson, P. J., Doyle, L. W., Gemmill, A. W., Lee, K., . . . Inder, T. (2010). Early sensitivity training for parents of preterm infants: Impact on the developing brain. *Pediatric Research, 67,* 330–335.

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory modulation disorder. *American Journal of Occupational Therapy, 61*(2), 228–238.

Miller, L. J., Neilson, D. M., & Schoen, S. (2012). Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology. *Research in Developmental Disabilities, 33*(3), 804–818.

Moberg, P. J., Agrin, R., Gur, R. E., Gur, R. C., Turetsky, B. I., & Doty, R. L. (1999). Olfactory dysfunction in schizophrenia: A qualitative and quantitative review. *Neuropsychopharmacology, 21,* 325–340.

Molina, B., Hinshaw, S. P., Swanson, J. M., Arnold, I., Vitiello, B., The MTA Cooperative Group. (Jensen, P. S., … 2009). MTA at 8 years: Prospective follow-up of children treated for combined type ADHD in a multisite study. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(5), 484–500.

Mouchet-Mages, S., Canceil, O., Willard, D., & Krebs, M.-O. (2007). Sensory dysfunction is correlated to cerebellar volume reduction in early schizophrenia. *Schizophrenia Research, 91,* 266–269.

Mullen, E. (1995). *Mullen Scales of Early Learning*. Circle Pines, MN: American Guidance Service, Inc.

Mulligan, S. (1996). An analysis of score patterns of children with attention disorders on the Sensory Integration and Praxis Tests. *American Journal of Occupational Therapy, 50*(8), 647–654.

Murray, D. W., Arnold, L. E., Swanson, J., Wells, K., Burns, K., Jensen, P., . . . Strauss, T. (2008). A clinical review of outcomes of the multimodal treatment study of children with attention-deficit/hyperactivity disorder (MTA). *Current Psychiatry Reports, 10*(5), 424–431.

Mutti, M. A., Martin, N. A., Sterling, H. M., & Spalding, N. V. (1999). *Quick Neurological Screening Test—3rd Edition*. Novato, CA: Academic Therapy Publications.

National Child Traumatic Stress Network. (n.d.). Facts and figures. Retrieved from http://www.nctsn.org/resources/topics/facts-and-figures

Niemi, A. (2017). Review of randomized controlled trials of massage in preterm infants. *Children, 4*(4), 21. doi:10.3390/children4040021

Olson, L. J., & Moulton, H. J. (2004a). Occupational therapists' reported experiences using weighted vests with children with specific developmental disorders. *Occupational Therapy International, 11*(1), 52–66. doi:10.1002/oti.197

Olson, L. J., & Moulton, H. J. (2004b). Use of weighted vests in pediatric occupational therapy practice. *Physical & Occupational Therapy in Pediatrics, 24*(3), 45–60.

Ornitz, E. M., & Ritvo, E. R. (1968). Perceptual inconstancy in early infantile autism. *Archives of General Psychiatry, 18,* 76–98.

Panksepp, J. (2004). *Affective neuroscience: The foundations of human and animal emotions*. New York, NY: Oxford University Press.

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J. A., Miller, L. J., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy, 61*(2), 216–227.

Parham, L. D., & Ecker, C. (2007). *Sensory Processing Measure - Home Form*. Los Angeles, CA: Western Psychological Services.

Parham, L. D., Smith Roley, S., May-Benson, T., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on effectiveness of Ayres Sensory Integration®. *American Journal of Occupational Therapy, 65*(2), 133–142. doi:10.5014/ajot.2011.000745

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (2007). Somatosensory function in boys with ADHD and tactile defensiveness. *Physiology and Behavior, 90,* 553–558.

Patterson, J. V., Hetrick, W. P., Boutros, N. N., Jin, Y., Sandman, C., Sterm, H., . . . Bunney, W. E. (2008). P50 sensory gating ratios in schizophrenics and controls: A review and data analysis. *Psychiatry Research, 158,* 226–247.

Perna, G., Dario, A., Caldirola, D., Stefania, B., Cesarani, A., & Bellodi, L. (2001). Panic disorder: The role of the balance system. *Journal of Psychiatric Research, 35,* 279–286.

Perry, B. D. (2009). Examining child maltreatment through a neurodevelopmental lens: Clinical applications of the neurosequential model of therapeutics. *Journal of Loss and Trauma, 14,* 240–255. doi:10.1080/15325020903004350

Perry, W., Minassian, A., Lopez, B., Maron, L., & Lincoln, A. (2007). Sensorimotor gating deficits in adults with autism. *Biological Psychiatry, 61,* 482–486.

Pfeiffer, B. (2002). The impact of dysfunction in sensory integration on occupations in childhood through adulthood: A case study. *Sensory Integration Special Interest Section Newsletter, 25*(1), 1–2.

Pfeiffer, B., Brusilovskiy, E., Bauer, J., & Salzer, M. (2014). Sensory processing, participation, and recovery in adults with severe mental illness. *Psychiatric Rehabilitation, 37,* 289–296.

Pfeiffer, B., Daly, B. P., Nicholls, E. G., & Gullo, D. F. (2015). Assessing sensory processing problems in children with and without attention deficit hyperactivity disorder. *Physical & Occupational Therapy in Pediatrics*, *35*(1), 1–12. doi:10.3109/01942638.2014.904471

Pfeiffer, B., & Kinnealey, M. (2003). Treatment of sensory defensiveness in adults. *Occupational Therapy International*, *10*(3), 175–184.

Pfeiffer, B., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Research Scholars Initiative—Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy*, *65*(1), 76–85. doi:10.5014/ajot.2011.09205

Phillips, L. K., & Seidman, L. J. (2008). Emotion processing in persons at risk for schizophrenia. *Schizophrenia Bulletin, 34,* 888–903.

Piek, J. P., & Dyck, M. J. (2004). Sensory-motor deficits in children with developmental coordination disorder, attention deficit hyperactivity disorder and autistic disorder. *Human Movement Science, 23*(3/4), 475–488. doi:10.1016/j.humov.2004.08.019

Porges, S. W. (2008). The polyvagal theory: New insights into adaptive reactions of the autonomic nervous system. *Cleveland Journal of Medicine, 75*(suppl X), S1–S5.

Rahkonen, P., Lano, A., Pesonen, A., Heinonen, K., Raikkonen, K., Vanhatalo, S., . . . Metsaranta, M. (2015). Atypical sensory processing is common in extremely low gestational age children. *Acta Paediatrica, 104*(5), 522–528.

Reynolds, C. R., Pearson, N. A., Voress, J. K., & Frostig, M. (2002). *Developmental Test of Visual Perception—Adolescent and Adult*. Austin, TX: Pro-Ed.

Reynolds, S., & Lane, S. J. (2009). Sensory overresponsivity and anxiety in children with ADHD. *American Journal of Occupational Therapy, 63,* 433–440.

Reynolds, S., Lane, S. J., & Richards, L. (2010). Using animal models of enriched environments to inform research on sensory integration intervention for the rehabilitation of neurodevelopmental disorders. *Journal of Neurodevelopmental Disorders, 2,* 120–132. doi:10.1007/s11689-010-9053-4

Richter, E. W., & Montgomery, P. C. (1989). *Sensorimotor Performance Analysis*. Hugo, MN: PDP Press.

Rogers, S. J., & Ozonoff, S. (2005). Annotation: What do we know about sensory dysfunction in autism? A critical review of empirical evidence. *Journal of Child Psychology and Psychiatry, 46*(12), 1255–1268.

Rohricht, F., & Priebe, S. (2006). Effect of body-oriented psychological therapy on negative symptoms in schizophrenia: A randomized controlled trial. *Psychological Medicine, 36,* 669–678.

Roid, G., Miller, L. J., Pomplun, M., & Koch, C. (2004). *Leiter International Performance Scale–3rd Edition*. North Tonawanda, NY: Multi-Health Systems Inc.

Sahoo, S. K., & Senapati, A. (2014). Effect of sensory diet through outdoor play on functional behaviour in children with ADHD. *The Indian Journal of Occupational Therapy, 46*(2), 49–54.

Sameroff, A. J., & Chandler, M. J. (1975). Reproductive risk and the continuum of caretaking casualty. In F. D. Horowitz, M. Hetherington, S. Scarr-Salapatek, & G. Siegel (Eds.), *Review of child development research: Vol 4* (pp. 187–244). Chicago, IL: University of Chicago Press.

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kelly, D. (2013). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders, Online First*. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., Hunt, J., & Benevides, T. (2012). Occupational therapy using sensory integration to improve participation of a child with autism: A case report. *American Journal of Occupational Therapy, 66*(5), 547–555. doi:10.5014/ajot.2012.004473

Schaaf, R. C., & Nightlinger, K. (2007). Occupational therapy using a sensory integrative approach: A case study of effectiveness. *American Journal of Occupational Therapy, 61*(2), 239–246. PMID: 17436846. doi:10.5014/ajot.61.2.239

Schilling, D. L., Washington, K., Billingsley, F. F., & Deitz, J. (2003). Classroom seating for children with attention deficit hyperactivity disorder: Therapy balls versus chairs. *American Journal of Occupational Therapy, 57*(5), 534–541.

Schore, A. (1994). *Affect regulation and the origin of the self: The neurobiology emotional development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Shaffer, R. J., Jacokes, L. E., Cassily, J., Greenspan, S. I., Tuchman, R. F., & Stemmer, P. J. (2001). Effect of Interactive Metronome training on children with ADHD. *American Journal of Occupational Therapy, 55*(2), 155–162.

Sherbourne, C. D., & Stewart, A. L. (1991). The MOS social support survey. *Social Science and Medicine, 32,* 705–714. doi:10.1016/0277-9536(91)90150-B

Silberman, S., & Sacks, O. (2015). *NeuroTribes: The legacy of autism and the future of neurodiversity*. New York, NY: Penguin Books.

Silverstein, S. M., & Keane, B. P. (2008). Vision science and schizophrenia research: Toward a re-view of the disorder editor's introduction to special section. *Schizophrenia Bulletin, 37,* 681–689.

Simon, N., Pollack, M., Tuby, K., & Stern, T. (1998). Dizziness and panic disorder: A review of the association between vestibular dysfunction and anxiety. *Annals of Clinical Psychiatry, 10*(2), 75–80.

Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences, 7,* 8, 343–348.

Smith Roley, S., Parham, L. D., Mailloux, Z., Schaaf, R. C., & Cermak, S. (2014). Sensory integration and praxis patterns in children with autism.

American Journal of Occupational Therapy, 69(1), 506–513. doi:105014/ajot.2014.010652

Sparrow, S. S., Cicchetti, D. V., & Balla, D. A. (2005). *Vineland Adaptive Behavior Scales Second Edition (Vineland II)*. Circle Pines, MN: AGS.

Staab, J. P. (2017). Functional and psychiatric vestibular disorders. In J. M. Furman & T. Lambert (Eds.), *Handbook of clinical neurology, 137* (3rd series, pp. 341–351). Atlanta, GA: Elsevier.

Stewart, L., & White, P. (2008). Sensory filtering phenomenology in PTSD. *Depression and Anxiety, 25,* 38–45.

Substance Abuse and Mental Health Services Administration. (2014). SAMHSA's concept of trauma and guidance for a Trauma-Informed Approach. Retrieved from https://store.samhsa.gov/system/files/sma14-4884.pdfhttp://www.samhsa.gov/traumajustice/traumadefinition/definition.aspx

Sutton, D., Wilson, M., Van Kessel, K., & Vanderpyl, J. (2013). Optimizing arousal to manage aggression: A pilot study of sensory modulation. *International Journal of Mental Health Nursing, 22*(6), 500–511. doi:10.1111/nm.12010

Toglia, J. P. (2011). The Dynamic Interactional Model of Cognition in Cognitive Rehabilitation. In N. Katz (Ed.), *Cognition, occupation, and participation across the lifespan* (3rd ed., pp. 161–201). Bethesda, MD: AOTA Press.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the Short Sensory Profile. *American Journal of Occupational Therapy, 61,* 190–200.

Turetsky, B. I., Bilker, W. B., Siegel, S. J., Kohler, C. G., & Gur, R. E. (2009). Profile of auditory information-processing deficits in schizophrenia. *Psychiatry Research, 165,* 27–37.

Twamley, E. W., Salva, G. N., Zurhellen, C. H., Heaton, R. K., & Jeste, D. V. (2008). Development and pilot testing of a novel compensatory cognitive training intervention for people with psychosis. *American Journal of Psychiatric Rehabilitation, 11,* 144–163.

U.S. Department of Education, Office of Special Education and Rehabilitative Services, Office of Special Education Programs. (2014). *36th Annual Report to Congress on the Implementation of the Individuals with Disabilities Education Act, 2014*. Washington, DC: U. S. Department of Education. Retrieved from http://www.ed.gov/about/reports/annual/osep

van der Kolk, B. A. (2006). Clinical implications of neuroscience research in PTSD. *Annals of the New York Academy of Sciences*, *1071*(1), 277–293. doi:10.1196/annals.1364.022

Van Rie, G. L., & Heflin, L. J. (2009). The effect of sensory activities on correct responding for children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *3*(3), 783–796. doi:10.1016/j.rasd.2009.03.001

VandenBerg, N. L. (2001). The use of a weighted vest to increase on-task behavior in children with attention difficulties. *American Journal of Occupational Therapy*, *55*(6), 621–628. doi:10.5014/ajot.55.6.621694

Vinall, J., & Grunau, R. E. (2014). Impact of repeated procedural pain-related stress in infants born very preterm. *Pediatric Research, 75,* 5, 584–587.

Vinogradov, S., & Nagarajan, S. (2017). Association of sensory processing with higher-order cognition and functioning in schizophrenia. *JAMA Psychiatry, 74*(1), 17–18. doi:10.1001/jamapsychiatry.2016.2992

Vlcek, P., Bob, P., & Raboch, J. (2014). Sensory disturbances, inhibitory deficits, and the P50 wave in schizophrenia. *Neuropsychiatric Disease and Treatment, 10,* 1309–1315.

Ware, J. E., Snow, K. K., Kosinski, M., & Gandek, B. (1993). *SF–36 Health survey manual and interpretation guide*. Boston, MA: New England Medical Center, The Health Institute.

Watling, R. L., & Dietz, J. (2007). Immediate effect of Ayres's sensory integration-based occupational therapy intervention on children with autism spectrum disorders. *American Journal of Occupational Therapy, 61,* 574–583. doi:10.5014/ajot.61.5.574

Watling, R. L., Deitz, J., & White, O. (2001). Comparison of sensory profile scores of young children with and without autism spectrum disorders. *American Journal of Occupational Therapy, 55*(4), 416–423.

Watling, R. L., Deitz, J., Kanny, E. M., & McLaughlin, J. F. (1999). Current practice of occupational therapy for children with autism. *American Journal of Occupational Therapy, 53,* 498–505.

Weisman, O., Magori-Cohen, R., Louzoun, Y., Eidelman, A. I., & Feldman, R. (2011). Sleep-wake transitions in premature neonates predict early development. *Pediatrics, 128,* 706–714.

Wells, A. M., Chasnoff, I. J., Schmidt, C. A., Telford, E., & Schwartz, L. D. (2012). Neurocognitive habilitation therapy for children with fetal alcohol spectrum disorders: An adaptation of the Alert Program. *American Journal of Occupational Therapy, 66,* 24–34. doi:10.5014/ajot.111.002691

Wiglesworth, S., & Farnworth, L. (2016). An exploration of the use of a sensory room in a forensic mental health setting: Staff and patient perspectives. *Occupational Therapy International, 23,* 255–264.

Williams, M. S., & Shellenberger, S. (1996). *How does your engine run? A leader's guide to the Alert Program for self-regulation*. Albuquerque, NM: Therapy Works.

Williamson, G. G., & Anzalone, M. E. (2001). *Sensory integration and self-regulation in infants and toddlers: Helping very young children interact with their environment*. Washington, DC: Zero to Three Publications.

Wolke, D., Jaekel, J., Hall, J., & Baumann, N. (2013). Effects of sensitive parenting on academic resilience of very preterm and very low birth weight adolescents. *Journal of Adolescent Health, 53*(5), 642–647.

Wolraich, M., Brown, L., Brown, R. T., DuPaul, G., Earls, M., Feldman, H. M., . . . Visser, S. (2012). Subcommittee on Attention-Deficit/Hyperactivity Disorder; Steering Committee on Quality Improvement and Management ADHD: Clinical practice guideline for the diagnosis, evaluation and treatment of attention deficit/hyperactivity disorder in children and adolescents. *Pediatrics, 128*(5), 1007–1022.

Yeap, S., Kelly, S. P., Reilly, R. B., Thakore, J., & Foxe, J. J. (2009). Visual sensory processing deficits in patients with bipolar disorder revealed through high-density electrical mapping. *Journal of Psychiatry Neuroscience, 34*(6), 459–464.

Yochman, A., Parush, S., & Ornoy, A. (2004). Responses of preschool children with and without ADHD to sensory events in daily life. *American Journal of Occupational Therapy, 58,* 294–302.

PART
VI

CASES



CHAPTER

20

Planning and Implementing Intervention Using Sensory Integration Theory

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"Would you tell me, please," [asked Alice,] "which way I ought to walk from here?" "That depends a good deal on where you want to get to," said the Cat. "I don't much care where," said Alice. "Then it doesn't matter which way you walk," said the Cat. "—so long as I get somewhere," Alice added as an explanation. "Oh, you're sure to do that," said the Cat, "if you only walk long enough."

—Carroll, 1923, p. 69

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

✔ Utilize a process of goal setting and intervention planning with particular children.

✔ Understand the systematic application of clinical reasoning as it pertains to Ayres Sensory Integration® (ASI).

Purpose and Scope

In this chapter, we provide a brief overview of goal setting and intervention planning, based on assessment findings. We illustrate decision-making associated with Ayres Sensory Integration® (ASI) methods with Kyle, one of the children whose evaluation data we had presented in Chapter 11 (Interpreting and Explaining Evaluation Data). We discuss not only aspects of the intervention that went "according to plan" but also some of the difficulties we encountered.

Introduction

Intervention consists of two phases: planning and implementation. Each depends on the other. That is, unless implementation is preceded by well-constructed plans, intervention becomes haphazard at best. Similarly, unless planning is followed by skillful implementation, the plan dies. The plan has three parts:

1. Setting goals and objectives as guided by the assessment data; we predict how a child will *act or interact* differently because of intervention.
2. Determining intensity, duration, location, and type of service delivery.
3. Developing ideas about intervention that reflect sensory integration (SI) theory and other practice approaches as needed; furthermore, we develop a general idea about activities to meet the goals as well as optimal characteristics of the intervention environment.

Certain goals are best met through direct service, whereas others are met through coaching (Hinojosa & Segal, 2012). If, for example, a child has low postural muscle tone and decreased postural stability, we may propose direct intervention characterized by activities that provide enhanced vestibular and proprioceptive input. If the same child is also distractible and gets into trouble at school, we may propose to coach the teacher to help alter tasks and the school environment to accommodate the child's needs.

A plan helps ensure that intervention is mutually agreeable to children, caregivers, significant others, and the therapist. The plan also ensures that intervention is conducted as efficiently and effectively as possible and contributes to enhanced participation in everyday life. Evidence on effectiveness, along with available resources and constraints, guides the plan.

Kyle Revisited

Kyle was 6½ years old. He lived with his parents, brother, and two sisters. Kyle's parents, Mr. and Mrs. P., described him as bright, active, and loving. They reported that he is sensitive to the fact that he is less coordinated than his siblings. Despite their best attempts at being patient, they find that Kyle is often the child who is reprimanded for being too active or not paying attention, which is eroding his self-esteem. Mrs. P.'s greatest concerns were Kyle's lack of friends and negative self-concept, even more than his incoordination or difficulty with handwriting.

HERE'S THE EVIDENCE

Recent research conducted with children diagnosed with autism spectrum disorders (ASDs; Bulkeley, Bundy, Roberts, & Einfeld, 2016; Dunn, Cox, Foster, Mische-Lawson, & Tanquary, 2012; Dunstan & Griffiths, 2008; Schaaf et al., 2013) suggested that both classic ASI and coaching interventions are promising but that sensory-based interventions (SBIs) of the type often included in coaching were variably successful. (See also Chapter 17, Using Sensory Integration Theory in Coaching, and Chapter 21, Planning and Implementing Intervention: A Case Example of a Child with Autism.)

Intervention proceeds in the manner suggested by the plan. Although this idea seems rather simplistic, translating a plan into action requires a different kind of reasoning than planning itself. The logic of the planning process is fairly linear, but the logic used when conducting intervention is more dialogic, a kind of ongoing "conversation" between a therapist and a child (Dunkerley, Tickle-Degnen, & Coster, 1997; Mattingly & Fleming, 1994) or a coaching partner (Rush & Shelden, 2011).

Conducting the Comprehensive Evaluation

When evaluating Kyle, we interviewed his parents and teacher; observed him at school; and administered a variety of assessments, including structured and unstructured observations in the clinic; the Sensory Profile2 (SP2) (Dunn, 2014), a questionnaire completed by the teacher and parents; and performance testing using the Sensory Integration and Praxis Tests (SIPT; Ayres, 1989). See Chapter 11 (Interpreting and Explaining Evaluation Data) for an additional description of Kyle's evaluation.

Generating Hypotheses

We concluded that Kyle's difficulties were based, at least in part, on sensory integrative dysfunction. More specifically, Kyle appeared to have a vestibular and proprioceptive processing disorder that was manifested in postural difficulties. His poor vestibular and proprioceptive processing appeared to have resulted in bilateral integration and sequencing (BIS) deficits and likely contributed to poor visuomotor skills, constructional abilities, and form and space perception. Furthermore, Kyle showed sensory modulation dysfunction in the form of tactile defensiveness and, to some extent, with the modulation of auditory input. The SP2 also identified the presence of behavioral and emotional issues (i.e., lowered self-esteem and poor frustration tolerance) related to difficulties with sensory modulation. Both the SP2 and clinical observations indicated that Kyle was highly distractible and overly active. We explained our findings to Mrs. P. and interpreted her concerns in light of these findings.

HERE'S THE POINT

- Challenges to a child's participation lay the foundation for the evaluation process, providing insights into areas of concern.
- A comprehensive evaluation includes standardized tools, observations, and interviews. The therapists' frame of reference guides the choice of assessments.
- Based on assessment results, the therapist generates hypotheses, making way for establishment of goals.

Developing and Setting Goals and Objectives

We began by asking Mr. and Mrs. P. how they wanted occupational therapy services to benefit their family. We used SI theory to offer explanations for Kyle's test results and their concerns. We discussed ways in which Kyle's challenges affected participation and the people around him. We asked for confirmation, clarification, and correction of our perceptions. Together with Mr. and Mrs. P., we formulated four important goals to guide intervention.

With regard to Mrs. P.'s primary concerns, we speculated that two things contributed to Kyle's negative beliefs about himself and the difficulties he had interacting with peers. These were:

1. Poor motor coordination, which interfered with his ability to perform the same kinds of skilled activities that his peers easily performed
2. Distractibility and increased activity, which resulted in Kyle's being reprimanded more frequently than peers or siblings

Mr. and Mrs. P. agreed with this assessment. We determined that our goals should reflect each of these major areas of concern. In addition to setting goals to address contributors to his poor self-esteem, we also decided to set goals that directly reflected the parent's primary concerns.

Modifying Kyle's Beliefs About Himself

Kyle's expectations that he would fail seemed to be both a cause of some of his difficulties and a result of others. Because he knew he lacked skills, he avoided certain activities. In avoiding them, he became more sedentary, which, given his underactive vestibular-proprioceptive processing, increased anxiety and created difficulty regulating arousal and activity levels. Additionally, he deprived himself of opportunities to practice skills. He fell further and further behind his peers and came to believe, even more firmly, that he was "no good." When he was forced to do activities that he knew he could not do well (e.g., handwriting), he became anxious, and his performance deteriorated. When he became anxious, he also became overly active and overwhelmed. His behavior further deteriorated, and he was reprimanded for bad behavior. Therefore, he had more reason to believe he was "bad" and that others also viewed him that way. He often indicated that no one wanted to play with him and that he had no friends aside from his siblings.

Mr. and Mrs. P. concurred with this line of reasoning. They punctuated our conversation with examples that illustrated our developing "theory" of Kyle's beliefs and behavior. Based on our jointly held perceptions, we proposed that one general goal for our intervention would be to help Kyle develop a belief that he would succeed at activities that he valued (i.e., self-efficacy) and that were appropriate for his age. Kyle's parents thought this was an important goal. However, we wanted to be sure that we could evaluate Kyle's progress toward meeting that goal at the end of 6 months' time. Thus, we needed to formulate specific objectives.

We asked Mr. and Mrs. P. what kinds of things they thought Kyle would do that would tell them that he had changed his beliefs about himself. How would Kyle act differently if he believed that he would succeed? What activities were both important to him and reflected skills appropriate to his age? We were unable to answer these questions by ourselves; only Mr. and Mrs. P. could fill in the details that would make the goal meaningful and measurable. Mrs. P. indicated that she would know that Kyle felt better about himself when, at least once a week, he willingly went off to play with other children in the neighborhood who are about his age. She felt that would mean he saw himself as a desirable friend and playmate.

We all recognized this objective might be difficult to meet, but it exemplified how Kyle would act as he began to feel better about himself. Kyle's going off to play with neighborhood children was something that his family cared about. Furthermore, objectives are a way of organizing actions; they are predictions, not contracts. If Kyle did not accomplish this objective, we would re-examine it to determine whether it was our predictions that were out of line or our methodology that was ineffective. Because the objective was readily observable by those closest to him, Kyle's family would be the ones to determine whether it had been met. They needed only to attend carefully to the evidence that he was or was not playing more with his peers.

Improving Kyle's Posture and Motor Skills

Both of Kyle's parents expressed a desire that Kyle develop increased stamina and the postural ability to sit comfortably in his chair and complete his schoolwork more easily. They also wanted him to enjoy playing some of the games and activities his peers loved—not to tire so quickly. We agreed that improving Kyle's posture and motor skills were important general goals. However, once again, we were at a loss to create specific objectives without knowing from the parents what he was currently able to do. That is, what specific skills did Kyle most need to develop? What should Kyle be able to do better in 6 months that would enable all of us to recognize that he had made progress? And how would it look if he performed a particular skill better?

We discussed this area for some time. His parents focused on riding his bicycle, pumping a swing, throwing a ball, catching a ball, handwriting, and buttoning. We talked about what seemed to be preventing him from doing each one. We reiterated that we were interested in selecting only the one or two skills that everyone (most importantly, Kyle) thought were most important. We felt certain that if Kyle changed in the ways that we specified, he would also develop additional skills simultaneously—ones not specified explicitly in objectives. These would be equally important, but we viewed them as an added bonus.

Mr. and Mrs. P. indicated that Kyle had, on numerous occasions, expressed a desire to be able to make the swing go by himself. That way, he could play on it as long as he wanted, rather than having to stop because his parents were tired of pushing him or had something else to do. Furthermore, Kyle loved swinging, but he was acutely aware that his 5-year-old sister had learned some time ago to pump the swing by herself and his 4-year-old brother could nearly do so. Thus, we decided that our objective would be that:

Kyle will independently pump the swing.

PRACTICE WISDOM

Two points regarding objectives cannot be emphasized strongly enough. First, objectives belong to caregivers and children. Unless they are meaningful, they are pointless. Second, intervention is "driven" by objectives.

Objectives that define achievement of a goal established by a team need not be agreeable to people who are not members of that team. However, *all team members* must agree that the objectives reflect the goals, and all team members should know whether or not a child has met the objectives (Mager, 1975).

We need not write objectives for every behavior related to a particular goal. Rather, targeting a few really meaningful objectives and working toward those collectively is much more critical. We then measure improvement in those areas as representative of the larger goal of improving his beliefs about his skills. A child might well make other gains in a particular area, and those gains may be equally important, but they would not have objectives attached to them.

PRACTICE WISDOM: SPECIFYING CRITERIA FOR OBJECTIVES

Readers familiar with the parts of an objective (i.e., learner, behavior, condition, and criterion) (Mager, 1975) will notice that we have not defined a criterion for measuring this objective. That is, we have not specified how well Kyle will have to pump his swing in order for us to say that he has met this objective. In our experience, the issue with pumping a swing is simply learning to do it. After children know how it feels to work *with* the swing, they can swing until they are ready to quit. Thus, we did not believe that the specification of a criterion was necessary. Because no criterion is specified, we assumed that Kyle would be able to do it whenever he wanted. Because that really was our intent, the lack of a criterion did not present a problem.

Improve Handwriting

Mrs. P. also expressed particular concern about Kyle's poor handwriting. She believed that the inordinate difficulty that he had with writing caused him to be slow and messy in school. This, in turn, resulted in his having to repeat his work or receiving negative feedback from his teacher. Many times, he brought home papers with the word *messy* scrawled across the top, which he was embarrassed to show his parents. We related his poor handwriting to the identified difficulties with visuomotor skills and form and space perception, and possibly also to his postural control challenges.

We agreed that improved handwriting was an appropriate goal for Kyle. Again, we began the process of discovering what exactly Mrs. P. meant by this goal. Should Kyle be able to write faster? If so, how fast? Should he be able to form letters more legibly? And, if so, what would constitute legibility? After discussing this, it became clear that Mrs. P. actually hoped that Kyle would improve in both areas; however, she recognized that he could probably not accomplish both within 6 months' time. We told her that, in our experience, children who wrote quickly could learn to write more legibly. However, children who became overly concerned with legibility often had a particularly difficult time learning to write more quickly. We agreed that the more important immediate objective was that:

> *Kyle will complete at least three of four written assignments within the allotted class time.*

Improving Kyle's Behavior

Kyle's behavior (i.e., distractibility, increased activity, and tendency to lash out at children who bumped into him) was a major concern for his parents and teacher. Kyle's behavior "got in his way" more obviously than anything else; it was probably the greatest single reason for the negative feedback that he got from those around him. Thus, we all agreed that improved behavior was an appropriate general goal.

We explored this difficulty more fully with Mr. and Mrs. P. so that we could formulate relevant objectives. We asked Mr. and Mrs. P. to tell us about circumstances when Kyle's behavior was most problematic (i.e., occurred frequently, was unavoidable, or in which his behavior was especially intolerable). Again, we asked how Kyle would behave differently in the next 6 months if he were making progress. Mr. and Mrs. P. talked about Kyle's behavior at some length. They mentioned the difficulties that they had taking him to restaurants, shopping malls, and their friends' homes. In the end, they concluded that, although all these created difficulties, they had learned to manage. When they anticipated that the situation would be particularly loud or crowded (e.g., a shopping mall during a holiday season), one of them either stayed home with Kyle (and often one or more of the other children) or they left some or all the children with a babysitter. They tried to take whole family outings to places where they knew Kyle would not be overstimulated or overwhelmed; they knew many such places. While this was not an ideal solution for optimal participation, Mr. and Mrs. P. were content, for the time being, with continuing this approach. However, Kyle's parents were quite concerned about his behavior at school. Nearly every week, his teacher called or sent a note home about Kyle's fighting or not paying attention to his work. Thus, we created one objective:

> *Kyle would not hit classmates who bumped into him accidentally.*

We knew this might be a difficult objective for Kyle to meet through sensory integrative intervention alone. Thus, we used a sensory strategy *based on* SI theory and recommended that Kyle have frequent activity or stretch breaks, particularly before a sedentary task or when waiting in line. The objective was written with the provision that the parent and teacher would allow Kyle access to sensory-regulatory strategies and the occupational therapist would teach everyone their appropriate use. With that in mind, we reframed the goal:

> *Given sufficient breaks and sensory-regulatory strategies, Kyle will not hit classmates who bumped into him accidentally.*

Besides fighting, the other significant aspect of Kyle's behavior at school was inattention to his work. When questioned about what exactly that meant, the parents indicated that Kyle rarely got his work finished on time. We hypothesized that this was related, at least in part, to the motor and postural concerns noted earlier. We decided that the objective (already specified under the goal to improve his motor skills) also pertained equally

PRACTICE WISDOM: MORE ON CREATING CRITERIA

Astute readers will note that the previous Practice Wisdom box pertaining to lack of a specified criterion applies here also. Because we have not specified a criterion, we assume that when Kyle meets the objective and is given reasonable accommodation, he will never hit a classmate who accidentally jostles him. This is precisely the criterion we have in mind. Although Mager (1975) indicated that perfect performance is rarely achievable, we believe that, in this case, it would be nonsensical to write an objective that said that Kyle would only hit a classmate once a month or once a year. Hitting other children because they accidentally bump into you is *never* acceptable. Furthermore, Kyle does not have a serious problem with violent outbursts; his mother indicated that his fighting occurs about twice a month and is triggered by very predictable occurrences (especially lack of sufficient breaks). Therefore, we believe that the objective, as specified, was attainable. We expected that Kyle, similar to most children, might occasionally "backslide." However, our objective is that he not respond to accidental touch by hitting.

well to the goal of improving his behavior. Thus, we also listed it under this goal:

> *Kyle will complete at least three of four written assignments within the allotted class time.*

Summary of the Intervention Plan

Although this process was difficult and time consuming, it was worth the effort. We all clarified our thinking and made explicit the most desirable outcomes of the intervention. Mr. and Mrs. P. said that the process helped them decide which things to focus on during the next several months. Before our discussion, they had felt guilty if they did not try to teach Kyle each time they interacted with him. Yet, they also felt that he needed time to "just be a kid." They were relieved to talk with someone who understood Kyle and could help them plan.

We then went on to recommend types of service delivery (e.g., coaching, direct intervention) that we would use to meet each objective. We recommended that Kyle obtain direct intervention in a clinic (private practice) setting and that his parents engage in coaching with the clinic-based therapist. We encouraged Mrs. P. to seek coaching services for the teacher from the occupational therapist at Kyle's school. We explained that direct service meant that a therapist intervened directly with Kyle in order to improve his skills (see also Chapter 13, The Science of Intervention: Creating Direct Intervention from Theory). Coaching meant that a therapist collaborated with the parents and the teacher to help each understand Kyle's behavior and needs better and to develop more effective strategies for working with him. Coaching could involve teaching parents and the teacher a simple procedure that they, in turn, would conduct with Kyle. (See also Chapter 17, Using Sensory Integration Theory in Coaching.)

Mr. and Mrs. P. agreed. Kyle's Individualized Education Program (IEP) team meeting was in another week, and Kyle's parents were glad to have had an opportunity to participate in goal setting before that meeting. They planned to take the goals that we had established to the meeting and incorporate them into Kyle's IEP. Kyle was fortunate to be eligible to receive occupational therapy services at school. Within the IEP meeting, we recommended school-based occupational therapy services via coaching. Kyle would receive direct intervention outside of school and, therefore, it did not appear in his IEP. However, we recommended that the clinic-based therapist and the school-based therapist touch base periodically. The suggestions we presented to Mr. and Mrs. P. and the team are summarized in Table 20-1.

HERE'S THE POINT

- Goals are established in conjunction with the major stakeholders in the child's life (e.g., parents, teachers) and are based on the outcome of the comprehensive evaluation process.
- Objectives help define goal achievement; they are predictions of change and reflect measurable outcomes.
- Once goals are established, approaches to intervention can be identified.

Setting the Stage for Intervention

The occupational therapist seeing Kyle in the clinic had taken special courses in the

TABLE 20-1 Contributions of Private Practice and School Occupational Therapists to Meet Kyle's Objectives

GOAL	OBJECTIVE	PRIVATE PRACTICE OCCUPATIONAL THERAPIST*	SCHOOL OCCUPATIONAL THERAPIST**
Develop belief that he will succeed at things he values (i.e., that he is a desirable friend and playmate)	At least once a week, willingly play with other children in the neighborhood who are about his age	Coach Kyle's mother on strategies to help Kyle enter a group; identify activities where he could invite a peer Work with Kyle to develop particular skills he needs to play with other children (e.g., sport or game)	Coach Kyle's teacher to help Kyle enter a group; develop ideas for activities that he could do with a partner
Improve (gross) motor skills	Independently propel a swing by pumping	*Work on proximal goals: improved bilateral integration and ability to plan and produce sequenced projected limb movements* Work with Kyle on his ability to propel clinic swings; point out similarities between clinic and playground swings	Coach Kyle's teacher to help Kyle with this skill on the playground
Improve (fine) motor skills (i.e., handwriting); improve behavior	Complete at least three of four written assignments within the allotted class time	*Work on proximal goals: improved postural ocular control, bilateral integration and sequencing, visuomotor skill, sensory modulation* Design home program specifically addressing handwriting speed	Coach Kyle's teacher regarding the location of Kyle's workspace (i.e., find quiet areas); adapt assignments
Improve behavior	Not hit classmates who accidentally bump into him	*Improve ability to modulate incoming sensory information;* explain tactile defensiveness and sensory modulation disorders to Kyle and his parents in terms they can understand; talk to Kyle about strategies he might use when he is feeling overwhelmed; coach Kyle's parents to help Kyle develop effective strategies	Explain relationship between Kyle's behavior, tactile defensiveness, and sensory modulation in educational terms; coach Kyle's teacher regarding location of Kyle's workspace (i.e., find quiet areas); find alternatives to other circumstances when fighting is a problem (e.g., while standing in line)

Note: Italics in the therapist's strategies reflect the proximal objectives established for Kyle; other strategies reflect a focus on distal objectives.
*Primary role: direct intervention; secondary role: coach to family.
**Primary role: coach to teacher.

implementation of ASI intervention and was a reliable intervener in this method. The therapist wanted to maximize Kyle's participation in the intervention process. In preparation for the first session, the therapist, as she always did, thought about three things:

1. The physical layout and activities and materials in the clinic
2. Types of activities that the child would enjoy
3. Types of interactions that the therapist hoped to promote as well as playful themes and games that the child might enjoy

Although these aspects of direct intervention become inextricably intertwined in a session, each has slightly different purposes and is, therefore, important enough to consider separately. Therefore, we discuss each briefly before illustrating how they came together in intervention.

Physical Layout of the Clinic

The therapist first considered the physical layout of the clinic. She knew that Kyle was easily overstimulated and found it difficult to maintain his attention when there were a lot of distractions.

She also knew that Kyle was exceedingly curious. If a lot of equipment was visible, he might run from item to item rather than choose one piece of equipment. Providing a visual chart to use in thinking about activities initially might help his focus as long as there was enough flexibility built into its use.

In choosing equipment, the therapist wanted to have some swings that could be suspended by two points because her plan was to incorporate linear movement. She kept out the glider, the bolster swing, the net hammock, and the trapeze for Kyle's first visit.

Anticipating that she might need activities that would help Kyle organize himself to stay focused, the therapist wanted to arrange the room so that it would be easy to create "small spaces" where distractions were minimized. Thus, she made available a barrel and a tent with cozy pillows. She also left out the Lycra swing, which could be suspended by two points for gentle swinging or by a single point to provide a cozy small space. She thought about some activities that he might enjoy in a confined space that also could help him increase his focus. The therapist thought of blowing and breaking bubbles, fishing with a Velcro fishing rod for Velcro fish, and locating and using a large pair of plastic tweezers to pick up plastic "bedbugs" (i.e., ½-inch diameter, brightly colored, bug-shaped plastic objects that belong to another game).

Selecting Activities

In thinking about activities, the therapist considered ways to engage Kyle and, at the same time, scaffold his ability to modulate and discriminate sensation, utilize effective postural responses, and plan and implement actions. The therapist planned to address four primary **proximal objectives** (Schaaf & Mailloux, 2015):

- Postural stability
- Bilateral coordination
- Visuomotor skills
- More typical responsivity to sensations

She hoped these would contribute to meeting the **distal objectives** of pumping the swing, completing assignments, and improved behavior. See Table 20-1 for the relationship between proximal and distal objectives in the column that describes the contributions of the private practice therapist.

SI theory suggests that Kyle's poor posture and BIS are linked to difficulties processing vestibular, proprioceptive, and visual sensations and would, therefore, be addressed through activities that provide multi-sensory sensation in the context of motivating activities. Activities that provide enhanced linear vestibular sensation and proprioception support the development of postural control and coordinated use of both sides of the body.

Although difficulties with visuomotor skill may stem from many sources, Kyle's evaluation suggested that his visual-motor difficulties resulted, at least in part, from poor processing of vestibular and proprioceptive sensations. Thus, the therapist planned to build visuomotor challenges into activities that provided enhanced vestibular proprioceptive sensation. (See Chapter 13, The Science of Intervention: Creating Direct Intervention from Theory.)

Kyle's over-responsivity to tactile and auditory sensations yielded defensive responses at home and school. Although the "best solution" for improving sensory modulation has not been determined, SI theory suggests that activities that promote calming and organization (e.g., swinging gently back and forth in a Lycra swing or wearing compression garments) support the acquisition of a regulated state and reduced defensiveness. An atmosphere of trust and safety in which the child controls important aspects of the activities (e.g., amount and type of sensation) is critical to modulating arousal and ensuring engagement. Therefore, while guiding the direction of the session, the therapist must guard against imposing sensation.

Based on what she knew of Kyle and her experience with other clients with similar problems, the therapist developed a working hypothesis

PRACTICE WISDOM

Schaaf and Mailloux (2015) described both proximal and distal objectives. They used the term *proximal* to refer to objectives targeting sensorimotor abilities and *distal* to refer to objectives targeting participation in everyday life. These terms assist therapists with practical reasoning by helping to clarify the relationship between the ultimate objectives of intervention (i.e., everyday activities) and the sensorimotor components hypothesized to underlie those activities.

and created ideas for activities that reflected her hypothesis. She would observe Kyle's behavior and seek information from his parents to determine whether her strategies were successful. If she did not have visible evidence within a few sessions that Kyle's defensiveness was decreasing, she would develop an alternative hypothesis and plan.

The therapist's "hunch" about Kyle's sensory defensiveness was that it was a major contributor to his heightened arousal. If this was the case, introduction of inhibitory vestibular, proprioceptive, or deep pressure sensation as well as the reduction of visual and auditory input should help to lower his arousal when necessary. She considered natural lighting, speaking in a quiet voice, and encouraging Kyle to spend time in quiet spaces.

Thinking About Interactions and Playful Themes

The therapist wanted to be sure that her actions and interactions with Kyle served to **"co-regulate"** him. That is, through therapeutic use of self and the repertoire of materials and activities that she made available, she created an environment that supported Kyle's ability to regulate himself.

The therapist thought first about providing choices to give Kyle a sense of control. She knew he liked pirates so together they could create a pirate story complete with boats, ropes, and treasure. The therapist's role would be to steer him toward equipment that would be organizing yet challenging. She had begun to consider this issue already in deciding which swings to leave in the room. For example, having left out the glider and the bolster swings, she could ask Kyle to select the swing that would be the boat. Realizing they might need paddles for the boat, the therapist also decided to leave out a bat and a ball and some swim noodles. She would ask Kyle to identify the paddles they would need to go to "Treasure Island."

The therapist thought about ways to build-in discussions of challenges that Kyle might experience and ways that he could overcome them. She wanted to develop strategies for him to use when things got difficult. For example, the pirates need a rest; where should they go? While they rested, they could make other plans for Kyle to use outside of therapy at times or in places, such as school, when he felt overwhelmed. The therapist knew that it might take many such conversations before he could actually use this information and that she would have to "check out" any strategies with his parents (and perhaps his teacher). She also thought about engaging Kyle in similar discussions about his poor motor coordination when the opportunities presented themselves.

The therapist recognized that asking a 6-year-old boy to engage in meaningful conversations about sensory integrative dysfunction was likely to be difficult and the play narratives were a safe way to engage in these discussions. However, she believed that a very important part of her intervention was to help him understand why he was unable to do some things and that made him neither "bad" nor "dumb" (words he frequently used to refer to himself). Furthermore, she believed that he must develop strategies for dealing with his own difficulties and that these strategies also were an important part of her intervention with him. The therapist knew that Mr. and Mrs. P. planned to spend time talking with Kyle in a similar fashion. She planned to touch base with them frequently so that their efforts would be complementary.

HERE'S THE POINT

- Treatment planning is multifaceted, requiring consideration of the physical environment, available equipment, planned activities, and anticipated therapist-child interactions.

Providing Intervention

Now that all the pieces were in place, the therapist was ready to begin. We describe several "snapshots" taken during the first 3 months of intervention. In so doing, we illustrate how the plan was translated into action and how the therapist resolved some of the difficulties that she encountered. We demonstrate how the therapist reflected, both in the moment and afterward.

The First Intervention Session

During their initial session together, the therapist gave Kyle a tour of the therapy room, pointing out several things that she thought might interest him. After the tour, she suggested that Kyle might want to try "flying" in the hammock (see Fig. 20-1). She kept several thoughts in mind.

FIGURE 20-1 Many young boys enjoy swinging prone in the net hammock. *Photo by Shay McAtee, printed with permission.*

First, she knew that Kyle, similar to many boys his age, was really into superheroes. The therapist showed him how he could do tricks the way a superhero does, such as rolling out of the hammock onto pillows on the floor. Second, the therapist saw the hammock as a way of providing enhanced vestibular and proprioceptive sensation and also requiring him to use postural responses against gravity. She knew that it would be easy to create activities in the hammock that required visual-motor skill, bilateral coordination, and projected action sequences.

Kyle was excited about trying the hammock. Anticipating that he might have difficulty getting into it, the therapist suggested they build a superhero house using the soft stairs to "enter" the house (hammock). Even so, on his first attempt to get into the hammock, Kyle ended up rolling out instead, landing on the pillow. Kyle was startled, but they laughed and tried again, the therapist silently guiding him, this time more slowly. The second time, Kyle succeeded. He immediately began to pull the handle that made the hammock bounce, and the therapist encouraged him to see how high he could go. Kyle called out, "I'm flying like Superman!" He seemed delighted with his accomplishment and yelled for his mother (who was observing from behind a one-way mirror) to watch.

The therapist noted that, as Kyle pulled on the ropes to propel himself, he tended to lose his grasp on the handles, so she recognized that she must adapt the activity. She grabbed a long dowel rod from the shelf behind her, held it at either end between her two outstretched arms, and entered into Kyle's game. "Hey, Superman!" she yelled. "Grab onto this branch and look in this window. I think there's someone who needs your help!" Kyle reached up and grabbed the bar with his arms outstretched. "Hold on," yelled the therapist. "Pull hard so you can come a little closer." As Kyle began to flex his arms, the therapist watched closely to make sure that his body and head remained extended. At the first sign of neck, hip, or knee flexion, she lowered the bar a little to reduce the amount of resistance.

"What do you see?" asked the therapist. Kyle replied, "There's a whole bunch of bad guys in there." The therapist suggested that maybe he had better fly for help because there were too many bad guys to take on alone. Kyle let go of the bar and swung back and forth several times, calling for Batman and Superwoman to come and help him.

Meanwhile, the therapist had pulled a cushion underneath Kyle and laid several beanbags on top of the cushion. She hoped to arrange the beanbags so they were high enough for Kyle to grab them as he flew by and so that he would do so without using total body flexion. After several more "peeks through the window," the therapist suggested that the superheroes might want to throw the beanbags into the hiding place to "take out" the bad guys.

The game continued with the therapist gradually altering the demands and watching Kyle's responses. By the time it was finished, Kyle was pushing himself with both hands, grabbing a beanbag or two on the way by, and throwing them at a target identified as the secret place. The therapist was impressed with the accuracy of his throw and with the amount of extension he was able to maintain. She cheered as he hit the target. The therapist told Kyle that this game would help him have stronger muscles and that throwing the beanbags was good practice for throwing a ball.

As Kyle grew tired, his throwing accuracy decreased, and he began to fall into flexion. He complained that his neck hurt and that he wanted to sit up to throw the beanbags. The therapist helped him out of the hammock. It was nearly time for the session to end anyway, but the therapist wanted to be sure his level of arousal was not too high before he left the clinic. Together they found flashlights, and the therapist hung the Lycra swing from a single point; she also lowered the lights in the room. Kyle sat in the swing and he and the therapist played a game of "I Spy," using the flashlights to point out the objects once the other person guessed what they were. Within a few minutes, Kyle was ready to put his shoes and socks back on. As they were leaving, the therapist spoke briefly with Mrs. P. Kyle was very excited to tell his mother about everything he had done, not knowing that she had seen it through the mirror.

One Week Later

Having had such a successful first session with Kyle, the therapist looked forward to repeating the same activity in the second session. However, Kyle announced, upon arriving for his second session, that he did not want to lie down to do anything; he only wanted to sit on the swing because lying down hurt his neck. Mrs. P. concurred that Kyle had complained about sore neck muscles for 2 days. However, she also said that she had told Kyle that his muscles were sore because they were getting stronger.

The therapist had to think quickly. Although she had planned to create activities for Kyle to do while sitting, she was afraid to create a lot of those activities at this point because it might be difficult to get him to go back to the prone position. The therapist had probably demanded too much of Kyle in the first session, and she should have had him spend less time in the prone position. However, she believed that he needed to work in the prone position because that was the best position to encourage maintained extension against gravity.

The therapist could have insisted that Kyle lie prone in the net if he wanted to do the activity. She could have explained to him that it would not work as well while sitting. She also could have helped him to create an activity while sitting, using a different swing, that probably would have been successful. However, the therapist believed it was important to give Kyle an active decision-making role. She wanted him to learn that he could adapt situations to make them turn out better. The therapist knew that Kyle probably would learn on his own that using the prone position was better for doing this particular activity. Although the prone position was, in general, more difficult, the therapist believed that he would choose it because he had enjoyed the activity and the feelings he had when he succeeded.

The therapist also knew that when children try throwing from a sitting position in the hammock, they often come to realize on their own that the prone position is easier. Thus, the therapist decided to follow Kyle's lead. She and Kyle set up the hammock swing, the cushion with the beanbags, the target, and the pillows, in much the same way she had set them up the week before. Kyle sat in the swing and began pushing it with his feet. He soon found that it was difficult to reach the beanbags, and his throwing was very inaccurate because he had to throw around the sides of the hammock and hold on at the same time. After a few minutes, Kyle told the therapist that he thought it worked better when he was lying down.

Hoping that this would happen, the therapist agreed immediately. Kyle got out of the hammock and, this time, using soft bolsters and stairs, was able to climb in with very little assistance from the therapist. He seemed pleased with his accomplishment and quickly engaged in finding the beanbags and throwing them into the hiding place.

The therapist watched the time and his reactions closely. After about 10 minutes, and well before Kyle began to appear fatigued, she suggested that they "find another secret hiding place" from a different swing. This time she helped him to create an activity that he could do well while sitting on the glider.

As the therapist reflected on her sessions with Kyle, she was surprised and pleased by some things. Kyle had been able to focus his attention remarkably well. He did not exhibit much of the distractibility that she had observed during testing and heard about at school. Thus, the therapist learned that, with the undivided attention of an adult and activities he found highly motivating, Kyle was able to pay attention to relevant stimuli. The therapist had set up the therapy room such that she kept distractions to a minimum, and Kyle successfully screened out those that were present. Although the therapist was pleased, she was not fooled into believing that Kyle would necessarily be able to focus his attention in more difficult situations, such as when he had less adult attention or there were more distractions. The therapist recognized the implications for the way she had structured the environment. She felt it might be beneficial not to be so careful that only certain swings remained in the room at subsequent sessions.

The therapist also knew that she was probably "buying time" with regard to Kyle's willingness to work in a prone position. She hoped she would be able to develop activities that are best done in the prone position that were highly motivating for at least a few more sessions. By then, Kyle might begin to find the prone position easier and be less resistant to it. However, she knew that if he balked, she probably would have to work primarily in sitting for a time and go back to the prone position as his postural stability improved.

Six Weeks Later

After working with Kyle weekly for 6 weeks, as the therapist anticipated, Kyle had become familiar with the activities and tried to "steer clear" of those that required a prone position. She had been able to bargain with him a little; at the current appointment, the therapist had created an activity to work on the timing of limb movements and on his ability to flex his neck and upper trunk against gravity. She hoped that this activity would carry over into his being able to pump the swing independently.

Kyle was standing on a pile of mats, the net swing slung around him. He was holding on with both hands. The therapist stood on the floor opposite him, far enough away that she would not get hit as he swung. She was holding a large hula hoop between her outstretched arms. On cue, Kyle jumped off the mats and extended his legs. The goal of the task was to lean back and flex his knees around the hoop. The therapist yelled, "Now!" a fraction of a second before he should bend his knees. After Kyle had successfully "grabbed" the hoop, the therapist pulled him up a little higher, watching to see how far she could move him without his losing control of his head and neck. After she had attained the best possible position, the therapist moved the hoop from side to side and back and forth, making "roaring" noises.

"Let go! Let go!" the therapist said again and again. "You'll never capture me, you mean old monster!" Kyle, fully involved in the activity, did let go after a few seconds, saying, "Okay, just one more chance to be good. But, if you do anything else bad, I'll be back to get you!" As soon as Kyle landed back on his mats, the therapist did something to make Kyle "attack" her again, and the game went on.

After a time, the therapist stopped telling Kyle when to flex his legs in order to grab the hoop because Kyle seemed no longer to require assistance. He continued to be successful at the activity. In fact, the therapist thought that Kyle was doing so well he might be able to shift to pumping the swing. The therapist feigned tiredness. She said to Kyle, "I need a break. Why don't you just swing by yourself for a few minutes?"

He continued to push off the mats, catching himself after each swing. The therapist watched for a while and then suggested he not stop so frequently. "You know," she said, "when your sister pumps the swing, it's like she's leaning back and reaching out with her legs to catch an imaginary hoop. After she catches it, she pulls it back with her. Then she reaches out for a new hoop.

And it just keeps going. Why don't you try that? Pretend I'm still standing there with that hoop."

Kyle thought for a while. Then he tried it once. He leaned back as he had when catching the hoop, but he flexed his knees too fast. Knowing that it had not worked, he caught himself on the mats. "Try again," the therapist urged. "But wait until I say 'now' to bend your legs."

Kyle jumped off the mats, and the therapist began to say quietly, "Now," just before he reached the full arc of the swing. At first, Kyle had trouble coordinating his leg and body movements, but gradually he began to coordinate the flexion and extension of his body with the flexion and extension of his legs. He did it very forcefully, and his swinging was jerky, but his timing seemed to be better. "See if I can do it without you telling me when," Kyle said. The therapist followed his lead and Kyle was able to pump the swing himself, although a little awkwardly. He practiced for a few minutes until it was time for the session to end.

Mrs. P. had been watching from behind the one-way mirror. She was beaming at Kyle as he entered the observation room. "We'll have to hurry home so you can practice before it gets dark. Your father will be very excited when he sees what you've learned," Mrs. P. said.

Two days later, Mrs. P. called to say that Kyle had mastered his first objective. "He's so excited," she said. "He spends every minute on the swing, practicing. His teacher sent a note home yesterday saying that he tried the swing at school for the first time. That's the first positive note we've gotten all year."

The therapist was also excited. She talked for several minutes with Mrs. P., and they decided that the next week, Kyle's individual session would be half as long. Mrs. P. requested that she spend the other half of the session with the therapist so they could begin working out a home program to address Kyle's handwriting problem. The therapist made a note to call the occupational therapist seeing Kyle at school.

Scaffolding Measurable Outcomes

In the context of the objective for Kyle to pump the swing independently, it would not be enough for the therapist to create activities to improve Kyle's flexion and bilateral coordination in a general way. Rather, she needed also to create activities that mimicked the actual process of pumping a playground swing, scaffolding his skills through intervention activities that "mimicked" the demands of a stated objective.

Another child might have an objective to go up and down stairs quickly and reciprocally. Similar to Kyle's, that child's intervention might also include activities to improve his BIS abilities. However, activities created for this client should involve bilateral movement and projected action sequences *using his feet* (e.g., sitting in the net hammock and pushing off a wall with his feet). At least a portion of those activities should be done in a vertical position, similar to actually climbing stairs. We provide an example of intervention for a child with needs and objectives similar to these in Chapter 22 (Viewing Intervention Through Different Lenses).

Developing a Home Program

When Mrs. P. and the therapist sat down together the next week, Mrs. P. mentioned that she thought she could already see progress in Kyle's handwriting. She had had only one note in the past month from Kyle's teacher indicating that he failed to get his work done on time. Nonetheless, Mrs. P. felt that a home program focusing specifically on handwriting would be helpful.

The therapist explained that the occupational therapist at school was coaching the teacher and that they had decided to adapt Kyle's assignments so that he had less written work. The school-based therapist had provided a device to put on Kyle's pencil to encourage a better grasp and a slant-top surface to promote better posture. Also, because of coaching, the teacher had decided to move Kyle's desk to a rear corner of the classroom, where his classmates rarely went. Both the school-based therapist and teacher were encouraged by the results. However, they too believed that a home program could be beneficial.

The therapist reminded Mrs. P. that Kyle's objective was to get his schoolwork done on time, which required writing more quickly. Thus, the home program would concentrate on speed rather than letter formation. She also told Mrs. P. that a home program should not be just "exercises" that they had to "cram" into their already busy schedules. Mrs. P. agreed. With three other active children, she did not have time to make sure Kyle did his home program. She continued to express the need to facilitate positive interactions with Kyle rather than setting up situations in which he might need to be reprimanded for his performance.

The therapist wanted Kyle to write without worrying about forming perfect letters. One idea she had was that Kyle could practice quickly writing simple phrases while he was watching a video or television (Benbow, 1982). Mrs. P. thought Kyle would love that idea. Kyle and his brother and sisters were allowed a minimum of screen time; they often protested this rule. If Kyle's home program called for half an hour of television or a video each night, all the children would be delighted.

From the school-based therapist, the private therapist obtained lists of the letters that Kyle should already know, those that Kyle was currently working on, and letters he would be working on in the near future. She and Mrs. P. constructed silly phrases such as "the duck barked" and "the cat flew." The plan was that Kyle would select one of those phrases each night and write it as many times as he could while he watched television. The therapist asked Mrs. P. to remind Kyle that he should "just write" and not pay attention to each letter. He should only need to look down at his paper when he started a new line. It did not matter if he made a mistake; he should just keep going. When they told Kyle of the plan, he thought it was a "great idea." He wanted to know if he could start that very night. He promised to bring his "homework" in each week to show the therapist.

In selecting this idea, the therapist considered that writing phrases without looking involved writing with reduced feedback. The therapist hoped Kyle would develop a better "feel" for the way to make each letter and that his speed would improve as he did so. Furthermore, she believed that the procedure should be fun and that it should increase the ease with which he wrote. That all the children in the family would be delighted with the "requirements" of Kyle's intervention was an added bonus.

Both Mrs. P. and the therapist believed that the home program was an important part of intervention. Thus, there was no question that they should use some of Kyle's intervention time to develop their ideas for it. In fact, they scheduled a similar time for a month later when they planned to develop strategies for helping Kyle to enter a group of children. They would also talk about having a friend join Kyle and the therapist in some of their sessions.

Although the home program that the therapist created for Kyle was guided by SI theory, it was a type of skills training. The therapist created the most effective intervention for Kyle by drawing from several compatible occupational therapy practice models.

After 4 Months

Our final "snapshot" of Kyle and the therapist was taken about 4 months after Kyle began intervention. Kyle had, in fact, made a new friend named Jason. Jason had recently moved next door to Kyle and was in his class at school. Kyle had invited Jason to join him at his "special gym class." This was Jason's first visit to the clinic, and the boys were very excited. Kyle had just completed giving Jason a tour of all the swings. The therapist had asked Kyle what he and Jason would like to do first. Kyle responded that they would like to "fly" in the nets. "It's really cool. You're gonna like it," he told Jason. "It's just like being Superman."

In response to Kyle's request, the therapist hung two nets from single suspension points 8 feet apart. She asked Kyle if he would like to play the "hockey" game that she and Kyle had devised together. Kyle agreed.

The game consisted of both boys swinging prone in the nets. Each had a long stick that he held at both ends. Off to each side, slightly behind each boy, was a stack of cardboard blocks. The object of the game was to use the sticks to hit a large ball that was centered in a small hula-hoop on the floor between them. Each boy tried to use the ball to knock over the other's stacks of blocks. The game continued until one boy's blocks were completely knocked over.

Kyle had played this game with the therapist. She saw it as a means of providing Kyle with enhanced vestibular and proprioceptive sensation while demanding bilateral projected actions. Kyle had gotten to be fairly good at this activity, and he took the lead with Jason, teaching him the rules and showing him how to get the ball into the net.

The two boys were engaged for several minutes in the activity. However, with the competition, Kyle got very excited. He began to swing the stick with one hand and accidentally hit Jason quite hard. Jason was clearly upset and yelled at Kyle, "Hey, that's too hard. We're just playing."

The therapist intervened. She suggested that the boys get out of the nets and get into a medium-sized box filled with dried lentils. They climbed in. Meanwhile, the therapist turned off the overhead lights and put flashlights in her pockets for each boy. Kyle was still overstimulated. He immediately began to throw lentils. The therapist intervened again before a full-blown lentil fight could develop. "Kyle," she said, "lie down in the corner here, and Jason and I will bury you, all but your head." The therapist knew, from past experience, that this was an activity that Kyle found calming.

The therapist and Jason began dumping containers full of the lentils on top of Kyle. When Kyle moved too much, uncovering a limb, Jason reminded him to be very still. After Kyle was completely covered, the therapist suggested that Jason lie down beside him, and she buried Jason. She talked to the boys in hushed tones, and Kyle calmed down noticeably. The therapist gave each boy a flashlight, and they played a modified game of "I Spy" for a while.

The therapist noticed Kyle's proximity to Jason in the lentil box; his tactile defensiveness was somewhat reduced. Mrs. P. had also observed this. In one of their conversations, Mrs. P. told the therapist that Kyle's fighting at school had been nearly eliminated.

The therapist recognized that being in the lentil box provided a good opportunity to talk with Kyle about developing strategies to use when he felt out of control. She began a discussion with the two boys about how it felt to be buried under all those lentils. Jason indicated that it made him feel calm, kind of the way he felt after he had just taken a bath. The therapist skillfully guided the conversation so that both boys contributed and so Kyle could see that even Jason sometimes felt overwhelmed by "too much stuff going on around him." Seeing that Kyle was very intrigued by this knowledge, the therapist probed a little more. "What do you do when you feel like that?" she asked. Jason answered that sometimes he went to his room to be alone and sometimes he just put his head down on his desk. Kyle did not contribute much to that part of the conversation, but he listened intently.

After a time, the therapist turned the lights back on and dumped some small plastic "bedbugs" into the lentil mixture. The boys spent the last few minutes of the session busily searching for them and picking them up with large plastic tweezers. The therapist had scattered the bedbugs so that they were closer to Kyle. By the end of the session, both boys had found an equal number of bedbugs. They climbed out of the box and got ready to go home, chatting about what they would do together the next time Jason accompanied Kyle to the clinic. They planned that date for 3 weeks later.

HERE'S THE POINT

- Therapy using ASI is both planned and flexible; clinical reasoning and problem-solving are skills crucial to the success of each session.
- Therapy activities are designed to capitalize on existing abilities and scaffold the development of more complex adaptive responses as progress is made toward established goals.
- Intervention may include a variety of service delivery options to meet the needs of the child and the family.

Summary and Conclusions

In this chapter, we demonstrated how one expert therapist took information that she gathered in evaluation, put it together with SI theory and other occupational therapy practice models, and developed and implemented an effective intervention plan. We emphasized the importance of working with caregivers to formulate objectives, and we described a therapist's reflections in action (Schön, 1983, 1987) as well as the resulting modifications.

We highlighted the reasoning of a clinic-based practitioner performing direct intervention. We referred only briefly to the coaching role of the clinic-based therapist and roles of the school-based therapist. We have done so partly because we emphasized coaching in Chapter 17 (Using Sensory Integration Theory in Coaching). We have *not* done so because we believe that the direct service role of the clinic-based therapist is any more important than the role of the school-based therapist.

Direct intervention, conducted by a skilled therapist, is a powerful approach to intervention for individuals who have sensory integrative dysfunction. However, it is only one avenue by which to address the difficulties that individuals encounter in daily life. Furthermore, intervention based on SI theory alone often is not enough to eliminate these difficulties. We believe that the greatest benefits are attained when a team of individuals pools its skills and knowledge, sets meaningful and achievable objectives, and implements an integrated approach to intervention.

Where Can I Find More?

Fisher, A., & Marterella, A. (2019). *Powerful Practice:* Fort Collins, CO: Center for Innovative OT Solutions.

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism.* Bethesda, MD: AOTA Press.

References

Ayres, A. J. (1989). *Sensory Integration and Praxis Tests*. Los Angeles, CA: Western Psychological Services.

Benbow, M. (1982, March). Problems with handwriting. Paper presented at Eunice Kennedy Shriver Center, Waltham, MA.

Bulkeley, K., Bundy, A., Roberts, J., & Einfeld, S. (2016). Family-centered management of sensory challenges of children with autism: A single-case experimental design. *American Journal of Occupational Therapy, 70,* 7005220040. doi:10.5014/ajot.2016.017822

Carroll, L. (1923). *Alice in Wonderland and Through the Looking Glass*. London, UK: John C. Winston.

Dunkerley, E., Tickle-Degnen, L., & Coster, W. (1997). Therapist-child interaction in the middle minutes of sensory integration treatment. *American Journal of Occupational Therapy, 51,* 799–805.

Dunn, W. (2014). *Sensory Profile2*. Bloomington, MN: Psych Corp.

Dunn, W., Cox, J., Foster, L., Mische-Lawson, L., & Tanquary, J. (2012). Impact of a contextual intervention on child participation and parent competence among children with autism spectrum disorders: A pretest-posttest repeated-measures design. *American Journal of Occupational Therapy, 66*(5), 520–528. doi:10.5014/ajot.2012.004119

Dunstan, E., & Griffiths, S. (2008). Sensory strategies: Practical support to empower families. *New Zealand Journal of Occupational Therapy, 55*(1), 5–13.

Hinojosa, J., & Segal, R. (2012). Building intervention from theory. In S. J. Lane & A. C. Bundy (Eds.), *Kids can be kids: A childhood occupations approach* (pp. 161–179). Philadelphia, PA: F. A. Davis.

Mager, R. (1975). *Preparing instructional objectives*. Belmont, CA: Fearon.

Mattingly, C. F., & Fleming, M. H. (1994). *Clinical reasoning: Forms of inquiry in a therapeutic practice*. Philadelphia, PA: F. A. Davis.

Rush, D. D., & Shelden, M. L. (2011). *The early childhood coaching handbook*. Baltimore, MD: Paul H. Brookes.

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kendra, D. (2013). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders, 44*(7) 1493–1506. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism*. Bethesda, MD: AOTA Press.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic.

Schön, D. A. (1987). *Educating the reflective practitioner*. San Francisco, CA: Jossey-Bass.

CHAPTER

21

Planning and Implementing Intervention: A Case Example of a Child with Autism

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Autism is neither a gift nor a curse. It just is what it is.
Focus on the person. They're the true gift.
—Stuart Duncan

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Understand and apply sensory integration (SI) principles for a child with autism spectrum disorder.
- ✔ Explain relevant research evidence that has guided intervention using SI for a child with autism spectrum disorder.
- ✔ Demonstrate how systematic, evidence-based, clinical reasoning is used for interpreting assessment data and identifying specific patterns of SI dysfunction, goal setting, intervention planning and implementation, and outcome measurement.
- ✔ Describe occupational therapy using an Ayres Sensory Integration® (ASI) approach for a child with autism whose participation challenges relate to difficulty processing and integrating sensation.

Purpose and Scope

In this chapter, we present Kendra, a child with autism spectrum disorder (ASD) experiencing difficulty with participation across many developmental areas. As we interpreted her participation concerns to be, at least in part, linked to inadequate sensory integration (SI), we describe our evaluation process to identify related strengths and needs. Determining that there are sensory integrative concerns, we then discuss goal setting and intervention planning. We present a sample treatment session in detail along with the therapist's clinical reasoning process throughout the session and Kendra's gains after 10 weeks of treatment.

Introduction

As was noted in earlier chapters, children with ASD show a high incidence of difficulties with sensory responsiveness and praxis. Consequently, many children with ASD have participation challenges that are impacted by these difficulties (Bar-Shalita, Vatine, & Parush, 2008; Bundy, Shia, Qi, & Miller, 2007; Schaaf & Case-Smith, 2014; Smith, Press, Koenig, & Kinnealey, 2005). The sensory integrative approach specifically targets the sensory motor difficulties impacting the child's participation in learning, social, daily living, and other activities. The therapist uses individually tailored sensory motor activities contextualized within a playful, child-centered approach that fosters **adaptive responses** to sensory motor challenges at the **just-right challenge**. Importantly, activities utilized in the therapeutic interaction are based on the child's specific sensory and motor needs that are identified through a comprehensive evaluation of sensory integrative functions. The therapist analyzes the findings from the assessment data to design individually tailored sensory motor activities that target the identified sensory motor deficits impacting the child's daily functioning. The therapist collaborates with the family and the child to identify goals and areas of priority along with a plan for intervention.

When direct therapy is warranted, the therapist follows the principles and practices of the Ayres Sensory Integration® (ASI) approach and sets up the environment to target the child's specific areas of need while allowing for collaborative, therapeutic interactions. The therapist then engages with the child to foster the child's participation with a keen eye on observation of the child's response to activities and spontaneously grades the activities to target the just right challenge. Some goals may be best met by adaptations to the environment or to the daily routines. For example, a child may experience difficulty attending to learning activities in the classroom because of decreased vestibular functioning, resulting in poor postural control. This child may benefit from a change in seating such as a movable chair or having his seat moved to a quiet spot. Environmental adaptations are made on an individual basis and must be monitored regularly to ensure they continue to target the child's needs. Further, when making environmental adaptations, it is important to consider the perspectives of both the teacher and the child and assure that they are acceptable and appropriate.

ASDs are among the most frequently occurring neurodevelopmental disorders, affecting one in every 59 children (Baio et al., 2018). As a lifelong condition, ASD often causes individuals to experience difficulty functioning in daily living activities, and this difficulty impacts their ability to participate fully in educational, leisure, social, and daily living activities while also impairing quality of life for themselves and their family (Bagby, Dickie, & Baranek, 2012; Schaaf, Toth-Cohen, Johnson, Outten, & Benevides, 2011). Hence, there is a need for evidence-based treatments for children with ASD that address these functional limitations. Parents reported that their children's sensory difficulties impact their ability to participate in everyday activities, and research has found that they are predictive of maladaptive behaviors in ASD (Jasmin, Couture, McKinley, Frombonne, & Gisel, 2009). Hence, it is important to consider whether and how difficulty processing and integrating sensory information is affecting the child's ability to function effectively in his or her various environments.

In this chapter, we present Kendra, a young girl with ASD, and describe the ways that her SI deficits impacted her own daily life as well as her family's routines. Following the evidence-based intervention protocol described by Schaaf and Mailloux (2015), we will describe Kendra's strengths, needs, and interests; the process of assessment and goal setting; and the course of her occupational therapy intervention using the SI frame of reference. Throughout the chapter, we will emphasize the reasoning associated with interpreting assessment data to design an intervention, and we will describe the intervention specifically tailored to achieve meaningful outcomes for Kendra.

Kendra Revisited

Identifying Participation Challenges

Kendra, age 4 years, 5 months, lives with her parents. She is their only child. Kendra was born full-term with no complications. Her mother is a self-described homemaker, and her father works in the field of marketing. Kendra was diagnosed with autism at 2 years 8 months of age and has been enrolled in a special education preschool class since she was 3 years of age. Her parents report that Kendra has challenges in daily activities at home—including refusal to try new foods, which impacts her participation in mealtime—and she requires maximal assistance for dressing, including needing help figuring out how to put on clothing and manage fasteners. Kendra also has difficulty participating in community outings, such as eating dinner with her family in a restaurant or going shopping in a store, because she becomes overwhelmed and distracted by the noise and people. She also has difficulty playing with other children, often running aimlessly around the playground and engaging in unsafe behaviors, such as jumping off playground equipment. Kendra's parents report that she has difficulty at school participating in learning activities and in playing with other children. She has difficulty participating in lunch time with the other children as she is very particular about the food she will eat. During lunch time, she also becomes overstimulated by the noise and activity in the lunchroom.

After observing Kendra at home and at school, the therapist noted that Kendra demonstrated difficulty organizing her behavior for learning in the classroom. Her learning space was disorganized and messy, and she had difficulty following simple classroom routines. She also appeared to be bothered by the feel of various classroom materials, such as clay and other tactile modalities, used during learning activities. At recess she generally ran about the playground and resisted any of her peers' attempts to engage her in play.

Conducting the Comprehensive Evaluation

The information derived from interviewing her parents, and from observations of Kendra in the clinic and school setting, led the therapist to suspect that some of Kendra's difficulties could be explained by difficulty processing and integrating sensory information. The therapist hypothesized that Kendra's unsafe behaviors on the playground and her constant running around may be associated with poor **praxis**; specifically, that she may be unable to generate plans for engaging in play. Further, the therapist proposed that Kendra's difficulties with organization of behavior for learning activities may also be related to poor praxis and an inability to make appropriate motor plans to organize her approach to learning tasks. The behavior of pushing away children who attempt to play with her seems likely because of her inability to tolerate the tactile input of other children. Kendra's difficulty generating plans to engage in play with others (i.e., poor praxis) also may contribute to this behavior. These clinical hypotheses led the therapist to conduct a comprehensive assessment of Kendra's ability to process and integrate sensations. To assess whether Kendra's participation challenges and goals were related to poor processing and integration of sensory information, the occupational therapy evaluation included the Sensory Integration and Praxis Test (SIPT; Ayres, 1989) and the Sensory Processing Measure (SPM) Home and School (Parham, Ecker, Kuhaneck, Henry, & Glennon, 2007).

The SIPT (Ayres, 1989) was administered to examine Kendra's ability to discriminate, integrate, and utilize visual, tactile, proprioceptive, and vestibular sensations as well as motor abilities, such as balance, bilateral coordination, motor imitation, and sequencing of actions. The SPM Home and School forms (Parham et al., 2007) also were administered to examine sensory modulation and processing behaviors and how such behaviors may be playing a role in Kendra's participation challenges. This assessment tool involves acquiring information and observations from parents and teachers on a child's behavior and participation in both the home and school environments. Observations of performance were made throughout the evaluation process.

As shown in Table 21-1, Kendra was able to complete only nine out of the 17 SIPT tests. She showed high tactile responsivity during the tactile tests and thus was unable to complete Manual Form Perception, Localization of Tactile Stimuli, Finger Identification, Graphesthesia, or Kinesthesia. She was unable to initiate useful strategies during the Constructional Praxis tests and threw the blocks across the room. She also refused to participate in the tests for Bilateral Motor Coordination and Motor Accuracy. Of the tests she did complete, her scores were very low on Praxis on Verbal Command, Postural Praxis, Oral Praxis, Standing and Walking Balance, and Post-Rotary Nystagmus, all of which can be seen in Table 21-1. She scored in the low average range on both tests of non-motor visual-spatial perception, Space Visualization, and Figure-Ground Perception, and her score on Design Copying, a visual motor test, was low.

Because almost half of the SIPT tests were not administered, drawing conclusions regarding specific patterns of SI dysfunction was not possible based solely on the results of the SIPT. However, there was some evidence for **dyspraxia** based on low scores on several praxis tests that she did complete. Poor tactile perception was also evident while attempting to administer items on the Finger Identification and Localization of Tactile Stimuli tests. This finding led the therapist to conclude that poor **somatosensory** processing

TABLE 21-1 Kendra's SIPT Z Score at Pretest

SIPT TESTS	PRE-TREATMENT SCORE
Tactile Perception Tests	
Manual Form Perception (MFP)	Not administered
Finger Identification (FI)	Not administered
Graphesthesia (GRA)	Not administered
Kinesthesia (Kin)	Not administered
Localization of Tactile Stimuli (LTS)	Not administered
Praxis Tests	
Constructional Praxis (CPr)	Not administered
Postural Praxis (PPr)	–3.00
Praxis on Verbal Command	–3.00
Oral Praxis (OPr)	–3.00
Sequencing Praxis (SPr)	–3.00
Tests of Posture, Balance, Bilateral Integration, and Vestibular Functions	
Bilateral Motor Coordination (BMC)	Not administered
Standing and Walking Balance (SWB)	–0.80
Post-Rotary Nystagmus (PRN)	–0.50
Visual Perception and Visual Motor Tests	
Motor Accuracy (Mac)	Not administered
Space Visualization (SV)	–0.85
Figure-Ground Perception (FG)	–0.05
Design Copying	–1.74

underlies the difficulties with praxis. Average scores on the vestibular and visual-spatial tests suggest adequate abilities in these areas.

On the SPM, Kendra scored in the definite dysfunction range in the areas of tactile responsivity, praxis, and social participation. These findings provided further evidence that Kendra's behaviors associated with selective eating and participating in learning activities that used a tactile medium as well as her difficulty tolerating other children's touch may be related to over-responsivity to sensation. Further, her low score on the praxis subscale supported the findings of poor praxis on the SIPT and support the therapist's reasoning that many of her difficulties with play and organization of behavior for learning in the classroom may be related to poor praxis.

HERE'S THE POINT

- The evaluation process begins by investigating a child's challenges with participating in his or her daily activities at home and school.
- Difficulties that are hypothesized to be related to poor SI or praxis indicate the need for examining functions such as **sensory perception** and **discrimination**, praxis, postural control, **bilateral integration**, and **sensory responsivity**.
- A combination of evaluation methods is recommended, including a standardized performance-based assessment of SI such as the SIPT, a caregiver questionnaire of sensory processing functioning and behavior such as the SPM, and Ayres Clinical Observations of postural control and motor coordination. Interviews with those who know the child well, such as parents and teachers, and a measure of occupational performance are also important.
- Synthesis of assessment data from multiple sources is necessary to identify the specific sensorimotor factors that are impacting the child's participation in his or her daily occupations and to begin the intervention planning process.

Generating Hypotheses

Assessment data from the SIPT and SPM were synthesized and analyzed in relation to common patterns of sensory integrative dysfunction defined in the literature (Mailloux et al., 2011; Mulligan, 1998). Kendra's assessment results indicated poor praxis (low score on SIPT Praxis tests and Praxis subscale of SPM). Poor tactile perception was also evident. Difficulty with sensory responsivity (also called poor sensory modulation) was apparent, specifically over-responsivity to tactile sensations. Many of the behavioral consequences of SI deficits, as depicted in Figure 1-6 presented in Chapter 1 (Sensory Integration: A. Jean Ayres' Theory Revisited), are consistent with Kendra's presentation, such as tactile over-responsivity, decreased ability to regulate her behavior, difficulty organizing her approach to learning, and difficulty playing with others.

Next, specific hypotheses were formulated to link assessment findings to the participation challenges noted. For example, difficulty at mealtime was linked to tactile sensitivity that included the oral area (noted on the SPM). Difficulty dressing was hypothesized to be related to poor praxis, whereas her difficulty participating in community activities, such as eating at a restaurant, was hypothesized as being related to tactile over-responsivity (SPM) and poor praxis. Kendra's difficulty participating in play with peers in the community or at school was hypothesized to be related to both poor praxis, resulting in difficulty creating strategies for engaging in play with others, as well as tactile hyper-reactivity, which impacted her acceptance of other children into her play space. Finally, Kendra's difficulty participating in learning activities in the classroom was hypothesized to be related to poor **praxis**, resulting in difficulty organizing motor plans for following the classroom routines during learning. Further, tactile over-responsivity was hypothesized to be limiting her participation in learning activities when materials with a lot of tactile input were used. In summary, the evaluation data revealed that Kendra's participation in home, community, and school activities was affected by poor praxis and tactile over-responsivity. The evaluation process ends with the initiation of the intervention planning process.

HERE'S THE POINT

- Analysis of assessment data provides the basis for identifying how sensory processing and integration deficits are affecting the child's behavior, participation challenges, and ability to perform daily tasks.
- Analysis is essential for guiding the intervention process, for developing meaningful therapy goals, and for assuring that intervention activities are targeted appropriately.

Developing and Setting Goals and Objectives

Intervention planning involved operationalizing each one of Kendra's identified problems or daily life challenges into a goal and then identifying desired outcomes. This step was followed by making decisions regarding the selection of intervention type and context, setting a schedule for intervention, and identifying specific intervention activities. Therapists engage in a process of clinical reasoning to make all these decisions, with consideration of the synthesis and interpretation of assessment data, child and parent priorities, contextual elements, the research evidence available on potential intervention approaches and strategies, as well as pragmatics such as the therapist's resources.

The goals set for Kendra were established based on the primary concerns of the parents and the teacher (e.g., participation in mealtime, community activities, dressing, learning activities, and play with other children) as well as a review of her **occupational profile** data. There was also clear evidence from multiple sources of evaluation data suggesting that these **participation** goals were at least partially caused by underlying deficits in SI and processing. Her goals focused on functional, participation-based outcomes: participation in mealtime, dressing, community activities such as eating at a restaurant with her family, learning activities at school, and play with her peers on the school playground.

Once goals were identified, **Goal Attainment Scaling (GAS)** (Kiresuk, Smith, & Cardillo, 1994; Mailloux et al., 2007) was used to identify the expected or desired outcome for each goal following 10 weeks of intervention. Then goals were scaled so that changes in outcome could be measured (Table 21-2). Each goal identified the underlying SI deficit or factor(s) hypothesized to be impacting Kendra's ability to perform an occupation-based activity or to participate in a meaningful area of occupation. All goals were broken down further into measurable components and scaled as follows: –2 = much less than expected outcome; –1 = less than expected outcome; 0 = expected level of performance; +1 = better than expected outcome; and +2 = much better than expected outcome (Kiresuk et al., 1994; Mailloux et al., 2007).

For instructional purposes, we focus on two specific goals related to improving Kendra's dressing and eating skills. These examples are used to illustrate how goals may be scaled and written, how progress toward goal achievement can be measured, and how the planning and implementation of intervention relates to these goals.

TABLE 21-2 Sample of Kendra's Intervention Goals Written Using Goal Attainment Scaling

Kendra will decrease oral-tactile over-responsivity as a basis for trying new foods and mealtime participation. Current level: When presented with new foods, Kendra will push them away and leave the table; if prompted to come back to the table, Kendra will have a tantrum.				
–2	–1	0 (expected outcome)	+1	+2
Kendra will taste one new food with no tantrum behaviors within the 10-week intervention period.	Kendra will taste two new foods with no tantrum behaviors within the 10-week intervention period.	Kendra will taste three new foods with no tantrum behaviors within the 10-week intervention period.	Kendra will taste four new foods with no tantrum behaviors within the 10-week intervention period.	Kendra will taste five new foods with no tantrum behaviors within the 10-week intervention period.
Kendra will show improved praxis as a basis for increased participation in dressing. Current level: Kendra requires frequent verbal directions and physical cues to don a shirt.				
–2	–1	0 (expected outcome)	+1	+2
Kendra will put on a t-shirt independently given four or more verbal re-directions.	Kendra will put on a t-shirt independently given three verbal re-directions.	Kendra will put on a t-shirt independently given two verbal re-directions.	Kendra will put on a t-shirt independently given one verbal re-direction.	Kendra will put on a t-shirt independently with no verbal re-directions.

PRACTICE WISDOM

GAS methodology has been applied most often for research purposes, although it is also effective for clinical purposes. GAS is a quantifiable alternative to the way in which occupational therapy goals and objectives are traditionally measured and provides a means of measuring individualized progress in functional areas. Using GAS methodology, expected level of performance for each goal can be set and then scaled with equal intervals between levels. An important part of writing, scaling, and measuring goals is describing the child's current level in each area. Further, when using the SI approach, it is helpful to identify the sensory motor factors that are hypothesized to be impacting each goal, as this information communicates the underlying sensory motor skills that are being addressed in treatment.

Context and Schedule for Service Delivery

Kendra demonstrated significant difficulty processing and integrating sensation, and, therefore, clinic-based intervention was believed to provide the level and intensity of services that she needed to address her goals. This environment provided opportunities for participation in active, sensory motor activities that were in keeping with Kendra's level of need and with therapy equipment that afforded varied opportunities for experiencing sensation and developing praxis. Individual sessions of clinic-based

HERE'S THE EVIDENCE

GAS has been shown to be an effective strategy for identification and measurement of individual goals and a valid outcome measure for psychosocial interventions for autism (Ruble, McGrew, & Toland, 2012). GAS has been used in three randomized controlled trials (RCTs) of SI (Miller, Coll, & Schoen, 2007; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf et al., 2013). Significant gains in GAS scores for the SI group were reported from a study of 24 children with sensory modulation difficulties by Miller and colleagues (2007). In a study of 37 children with ASD, Pfeiffer and colleagues (2011) reported the SI treatment group had significantly greater gains in GAS scores than the group receiving fine motor intervention. Using a manualized protocol, Schaaf and colleagues (2013) also reported significant gains in the SI group in comparison to the usual care group of a study with 32 children. These studies have found GAS to be a useful tool for documenting change in children with ASD, as it is sensitive, objective, and provides an individualized, and thus very relevant, outcome measure.

occupational therapy intervention using the SI approach were provided three times per week for 10 weeks or a total of 30 sessions during the 10-week period. This intervention was supplemented with environmental adaptations in the classroom to support her sensory motor needs and to enable her to participate more effectively in learning, play, and lunchroom activities. In addition, frequent interaction with her parents was accomplished during the individual therapy sessions (before or following each session), and these focused on increasing parental knowledge and understanding of how Kendra's sensory motor difficulties were impacting her ability to carry out her daily activities and routines. The therapist also reached out to Kendra's teacher to collaborate on problem-solving strategies to aid Kendra in addressing her challenges in school, and weekly check-in with the teacher was accomplished via e-mail, phone, or on-site visits. Intervention outcomes would be measured at both the proximal level (changes in sensory motor skills and abilities forming **proximal objectives**) and distal levels (change in her participation in dressing and mealtime forming **distal objectives**) as measured by GAS and daily charting.

Setting the Stage for Intervention

Treatment activities based on the principles of ASI were chosen, as the assessment results indicated difficulty processing and integrating sensation were impacting Kendra's performance in the areas reflected in her goals. The therapist considered the following questions when identifying preliminary ideas for intervention:

1. What were the specific sensory motor areas being targeted for Kendra?
   a. The assessment data revealed that tactile over-responsivity and poor praxis were primary factors impacting Kendra's participation in dressing, mealtime, community activities, learning activities, and play with other children. Therefore, activities heavily loaded with somatosensory (tactile and proprioceptive) input and that challenge her motor-planning abilities were emphasized.
2. What specific goals are being addressed?
   a. Participation in mealtime, participation in dressing, participation in community activities such as eating at a restaurant with her family, participation in learning activities at school, and participation in play with her peers on the playground at school were identified as goals for Kendra. Therefore, her therapist incorporated activities associated with these goals into the intervention whenever possible and selected therapeutic activities with these goals in mind.
3. What are Kendra's interests and strengths?
   a. Kendra enjoys puzzles and stuffed animals, and she likes active play, so these interests were incorporated into therapy sessions.
4. How might the clinic and specific activities be organized so that Kendra participates in sensory motor activities that address her areas of need and so that they provide her with the just right challenge?
   a. The intervention included opportunities for rich total-body tactile input combined with opportunities for moving her body in new and novel ways. This included access to a large ball pit, large mats, a climbing wall, and suspended Lycra fabric layers that Kendra could crawl through and around. Also, there were opportunities for oral-tactile activities, such as blowing bubbles or eating a tactile-rich food such as peanut butter.

In the previous chapter, we went through the reasoning process for setting up a treatment session with Kyle, and we provided snapshots and clinical reasoning from a series of therapy sessions. We also looked at gains made after 4 months of therapy. Here we provide a more detailed example of a single treatment session with Kendra, the reasoning used by the therapist as the session unfolded, and Kendra's outcomes after a 10-week treatment program. Additional treatment approaches and ideas can be found in Chapter 12 (The Art of Therapy) and Chapter 13 (The Science of Intervention: Creating Direct Intervention from Theory), respectively.

Providing Intervention

A Typical Treatment Session with Kendra

The therapist used the steps described previously to set up the treatment area with activities that might entice Kendra to play. Keeping in mind the goal of dressing, the therapist set up a small area with a bench where Kendra's shorts and t-shirt were laid out (each child has a spare pair at the clinic). Here Kendra could change into her shorts and t-shirt, allowing more of her skin to be exposed to the many tactile sensations that Kendra would hopefully engage with during the treatment session. This activity also gave her the opportunity to practice dressing. Further, in consideration of Kendra's tactile over-responsivity but need for somatosensory (tactile and proprioceptive) sensations to improve body awareness and praxis, the therapist had the large ball pit available. Access to the ball pit included a couple of options: Kendra could drag over the large foam wedge and place it next to the ball pit, or Kendra could climb into the ball pit by lifting her body over the edges. The therapist had a puzzle nearby because she recalled that doing puzzles was an activity that Kendra enjoyed. The therapist thought she and Kendra might play a game of finding puzzle pieces in the ball pit. As a second option, the therapist had the bolster swing hanging up with some small stuffed animals laid out around it. The therapist anticipated initiating functional play, such as "get on your horse and ride through the forest." In addition, an area for oral motor play and snack time was set up. This area had bubbles, whistles, and other mouth toys in a small container on the table, and there were some preferred and non-preferred snacks and drinks nearby. The entire therapy area had mats, and all equipment was checked routinely for safety.

As Kendra entered the therapy room, the therapist noticed that she seemed agitated. Her mother indicated that Kendra was fighting with her in the waiting area because she did not want to leave her stuffed animal toy, "Stuffy," behind. Kendra wanted to bring it into the therapy session. The therapist, seeing an opportunity to build rapport with Kendra, first reassured Mom that it was fine to bring Stuffy into the therapy session. She then asked Kendra if she wanted Stuffy to play with them today also. Kendra was excited by this idea and ran off to retrieve Stuffy. In order to continue building rapport and to engage Kendra in functional play, the therapist pretended that Stuffy was whispering in her ear and stated: "Oh—Stuffy wants to go swimming today. Let's get into our swim gear." The therapist used this opportunity to encourage Kendra to work with her to remove her shoes and change into the t-shirt and shorts. With additional supportive whispers from Stuffy, and some assistance from the therapist, Kendra was willing and able to change clothes. The therapist gently guided Kendra toward the ball pit and pretended that Stuffy was trying to get into the ball pit but was not able to climb over the side because she is too short. "Stuffy is struggling. Can you think of a way to help Stuffy climb into the pool?" The therapist might have placed her hand on the large foam wedge as a suggestion. If Kendra picked up on the cue, she would begin to drag the foam wedge over to the ball pit. If not, the therapist might use Stuffy to begin to push the wedge over and (struggling) note, "Stuffy wants to use the wedge to help her get in the pool. Can you help?" The hope was that Kendra would help push the large (and heavy) foam wedge to the ball pit. The therapist noted that this activity was providing good proprioceptive sensations for Kendra (i.e., working muscles against resistance), which she anticipated would help decrease Kendra's tactile over-responsivity in preparation for play in the ball pit. Once the wedge was in place, the therapist asked Kendra to show Stuffy how to climb the wedge to enter the ball pit. Kendra jumped in and then Stuffy followed. Once in the ball pit, Kendra and Stuffy "swam" around and took turns covering each other up with balls in a "hide-and-seek" game for about 10 minutes. The therapist continued expanding the play schemes as she was able.

The therapist was vigilant in attending to Kendra's mood, attention, and responses to the sensations of the ball pit, and the therapist was prepared to adjust the activity in order to maintain the just right challenge for Kendra. When Kendra showed signs of disorganization, the therapist encouraged Kendra and Stuffy to come out of the pool and dry off with a big fluffy towel, providing firm tactile input. To ensure that Kendra stayed regulated, the therapist was prepared to wrap Kendra in the towel and hold Kendra (and Stuffy) against the therapist's body with firm pressure. This was not necessary during this session. Here the therapist was using knowledge that deep pressure touch may help regulate Kendra's tactile over-responsivity and also provide additional input to improve tactile perception and body awareness. Once Kendra was ready, they returned to the ball pit, and the therapist and Kendra expanded the playful activities and motor plans. This modification of activities allowed Kendra to be constantly challenged at the "just right" level to encourage praxis, acceptance of tactile sensations, and opportunities for tactile and proprioceptive perception to build body awareness. The therapist also might have suggested that Kendra show Stuffy different ways to jump into the ball pit (e.g., jump and twist around; go in backward, etc.) to facilitate praxis. In the ball pit, the hide-and-seek play scheme might have been expanded to just body parts ("let's find Kendra's foot") to foster tactile perception, or Kendra and Stuffy might have shown each other different ways to "swim through the 'pool'" (back stroke, side stroke, etc.). If going well, the therapist might introduce some of the oral motor mouth toys from the snack table into the activities in the ball pit. For example, the therapist might encourage Kendra to bury herself in the ball pit and then blow on the whistles for Stuffy to find her or blow bubbles so that Stuffy can pop them. The therapist continued to expand the play activities and schemes to create more challenging praxis schemes and play themes until Kendra showed signs of wanting to move on.

Once the therapist felt that the ball pit activity had exhausted its therapeutic value, the therapist pretended that she was hungry. "Wow, that swimming really made me hungry! I'm wishing for a snack." This suggestion was to encourage Kendra to go to the snack table. Here Kendra was encouraged to make Stuffy a peanut butter sandwich (a non-preferred food for Kendra) with two slices of bread and peanut butter that was set out prior. Next, the therapist encouraged Kendra to show Stuffy how to bite the sandwich. As expected, Kendra did not comply, and the therapist suggested that blowing on whistles and other mouth toys might help Stuffy and Kendra be more willing to accept the food. As there was still no success, the therapist reconsidered Kendra's interests; recalling that Kendra liked to play with her mother's makeup, the therapist brought out some play makeup and a mirror. They put on lipstick and rouge. The therapist reasoned that Kendra's resistance to try non-preferred foods was related to oral-tactile over-responsivity. As the makeup play required tolerance of tactile sensations in and around the oral area, this helped Kendra accept oral sensations more readily. After a few minutes of play, the therapist showed Kendra that biting into the sandwich while wearing lipstick left a funny mark on the bread. Curious to try this herself, Kendra bit the sandwich to make the lipstick imprint!

After several minutes of snack time, the therapist recognized that it was time to transition back to the waiting room and let Kendra know that she and Stuffy must change out of their "swimsuits" and back into their regular clothes. The therapist took advantage of the sensory motor experiences during therapy that were used to build Kendra's body awareness as a basis for praxis and worked with Kendra to don her shirt. The therapist might have tapped Kendra's arm and pointed to the shirt sleeve as cues for Kendra to motor plan the placement of her arm in the sleeve. At each future session, the therapist will provide less cueing and encourage Kendra to complete more of the steps to dressing independently.

Kendra's mom had been sitting in the treatment room during this session. As they walked together back to the waiting area, the therapist talked with Kendra's mom about the reasons for playing in the ball pit and using makeup to encourage Kendra to try non-preferred foods. They discussed similar strategies that could be used at home to help Kendra with her **motor planning** and to expand her food repertoire. The therapist suggested they make a peanut butter sandwich at home tomorrow and include Stuffy in the lunch time activity. In addition, the therapist talked with Kendra's mom about how to set up Kendra's daily dressing tasks, suggesting that they work on dressing in the evenings when they are not rushed and have fewer time constraints.

Communication and collaboration with Kendra's parents were integral to the occupational therapy intervention. In addition, environmental adaptations were also incorporated into the treatment program. The effects of environmental stimuli on Kendra's ability to focus and attend were discussed, and strategies were identified to decrease environmental stimuli. For example, when dining in a restaurant, her parents were advised to choose a seating location that was away from highly trafficked areas. When eating dinner at home, parents were advised to turn off the TV and reduce other unnecessary auditory, visual, and tactile sensations. To minimize demands on motor organization and planning, her parents were encouraged to provide Kendra with simple one- or two-step directions when asking her to perform daily living tasks.

HERE'S THE EVIDENCE

Evidence for the **effectiveness** of ASI characteristic of the intervention approach used with Kendra is available from several studies, including Schaaf and colleagues (2013). The study by Schaaf and colleagues included children with autism, ages 4 to 8 years old, and used a randomized controlled research design. The results showed that the children in the treatment group (n = 17) who received 30 sessions of the intervention scored significantly higher ($p < .01$) on GAS, and they also did significantly better on measures of caregiver assistance in self-care ($p = 0.008$) and socialization ($p = 0.04$) than the usual care control group (n = 15).

Ongoing Clinical Reasoning

Tailoring intervention is done mostly by carefully observing the child and considering the child's behavioral responses during intervention. Observations were made and recorded throughout Kendra's intervention sessions. Her behavior during the first two treatment sessions was quite disorganized, and she required physical and frequent verbal prompts to engage in therapeutic activities. She tended to run around the room, shifting from task to task with little sustained, productive play. With guidance and structure from the therapist, Kendra began to become more organized in her approach to the therapeutic activities. A possible explanation for this is that as Kendra became better able to manage sensation, her behavior became more organized. As this shift occurred, the therapist engaged Kendra with more and more challenging activities that required increasingly sophisticated adaptive responses.

Another important component to the intervention is that the therapist followed Kendra's lead in the sample session described previously. Recall that although the therapist set out a puzzle with the intent to use it in the ball pit activity, the therapist instead adapted to a swimming play theme. This theme seems to flow nicely with Kendra's interest in having Stuffy join in the activity and shows that the therapist followed Kendra's lead and read her cues to adjust the treatment accordingly. Treatment in SI is more focused on the types of experiences that the child needs rather than the activity itself. A successful treatment session is one where the child is engaged in active, individually tailored sensory motor activities in a playful context. The activity itself is only the catalyst for this experience.

HERE'S THE POINT

- Skilled occupational therapists working in clinical settings use their clinical reasoning by considering the child's needs, goals, and interests, along with the available research evidence, for guiding their service delivery decisions and for orchestrating intervention sessions.
- Effective sessions using SI are playful. They are filled with social interactions that foster a strong therapeutic alliance between the child and therapist, while engaging the child in activities providing the just right challenge and resulting in adaptive responses.

Outcomes Following 10 Weeks of Intervention

The therapist had a systematic plan for measuring outcomes, namely changes in participation in mealtime and dressing measured by GAS and daily charting of behavior. In keeping with the goals, the therapist asked the parents to keep a daily log of new foods tried and the number of verbal directions Kendra required during dressing. To facilitate data collection, the therapist provided two charts—one for the refrigerator in the kitchen so the parents could mark new foods tried daily, and one posted in Kendra's bedroom where dressing generally took place. After 10 weeks of intervention, the therapist evaluated Kendra's progress. The data from the charts was entered into a spreadsheet, and charts were made to show change through time. The therapists also asked the parents to view the GAS and circle the level of attainment. Kendra's parents marked her goal attainment for trying new foods as +2 (far exceeds expected outcome) and for dressing as +1 (exceeds expected outcome), showing that she made notable progress on both goals. A semi-structured interview was also conducted with the parents, which provided additional information about how Kendra was doing in her daily activities. Qualitative data from the interview with Kendra's parents further informed the therapist of outcomes indicating that Kendra participated in dinner at a restaurant and is better able to regulate her behavior when out in the community, such as eating in a restaurant.

Although it is not generally recommended that the SIPT be re-administered in a time frame that is fewer than 6 months, Kendra was re-administered the SIPT as an exploratory measure. The therapist wanted to see if Kendra would be able to complete more of the tests than were attempted at her initial assessment, and the therapist wanted to compare pre- and post-treatment z-scores. Kendra had completed eight SIPT tests at pretest, and she completed all 17 tests at posttest. Positive changes were noted on the following tests:

- Oral Praxis (pre: –3.00 to post: –2.18)
- Standing and Walking Balance (pre: –3.00 to post: –1.85)
- Figure-Ground (pre: –0.05 to post: 1.03)
- Sequencing Praxis (pre: –3.00 to post: –1.00)
- Postural Praxis (pre: –3.00 to post: –1.00)

These improvements were reflected in her ability to participate in multi-step sensory motor activities in the clinic (e.g., climbing onto a foam pillow, holding onto a trapeze, and swinging into a ball pit filled with large pillows) as well as her ability to participate in multi-step tasks at home (e.g., the ability to get dressed by herself, excluding fasteners). Furthermore, these improvements in sensory motor abilities were likely key factors contributing to the positive gains she obtained toward achieving her intervention goals.

Summary and Conclusions

This chapter described a child with ASD who was experiencing participation challenges in daily living and learning activities that were hypothesized to be related to poor SI. Following a detailed history and occupational profile, Kendra's participation challenges were identified, as were her strengths and interests. Assessment of the sensory motor factors affecting these participation challenges was accomplished using the SIPT, select clinical observations, and by administrating the SPM. Data from these assessments were analyzed and interpreted, and hypotheses about the specific sensory motor factors affecting Kendra's participation challenges were identified. Intervention activities that targeted these factors were implemented with Kendra following the key principles of the SI approach. In addition, her parents were educated about the impact of Kendra's difficulty processing and integrating sensation on her behavior, and specific environmental adaptations were recommended and implemented. After 10 weeks (30 sessions) of occupational therapy using SI, Kendra achieved her goals, and her ability to participate in her daily activities had improved significantly.

As autism is a complex condition, it is important to consider that standard care typically involves a multifaceted approach. In addition to receiving occupational therapy, children with ASD typically have additional professionals involved in their care. This chapter demonstrated how Kendra's occupational therapist, as a valued team member, used SI theory and techniques as a powerful approach for addressing Kendra's participation challenges.

Where Can I Find More?

Miller-Kuhaneck, H. (2004). *Autism: A comprehensive occupational therapy approach* (2nd ed.). Bethesda, MD: American Occupational Therapy Association.

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism.* Bethesda, MD: AOTA Press.

Websites:

Autism Speaks: www.autismspeaks.org

Autism Research Institute: www.autism.com

SPD Foundation: www.spdfoundation.net

References

Ayres, A. J. (1989). *The Sensory Integration and Praxis Tests*. Los Angeles, CA: Western Psychological Services.

Bagby, M. S., Dickie, V. A., & Baranek, G. T. (2012). How sensory experiences of children with and without autism affect family occupations. *American Journal of Occupational Therapy*, *66*(1), 78–86.

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Zachary, W., Kurzius-Spencer, M., . . . Dowling, N. (2018). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years – Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *MMWR Surveill Summ*, *67*(No. SS-6), 1–23. DOI: http://dx.doi.org/10.15585/mmwr.ss6706a1

Bar-Shalita, T., Vatine, J., & Parush, S. (2008). Sensory modulation disorder: A risk factor for participation in daily life activities. *Developmental Medicine & Child Neurology*, *50*(12), 932–937. doi:10.1111/j.1469-8749.2008.03095.x

Bundy, A. C., Shia, S., Qi, L., & Miller, L. J. (2007). How does sensory processing dysfunction affect play? *American Journal of Occupational Therapy*, *61*(2), 201–208.

Jasmin, E., Couture, M., McKinley, P., Frombonne, E., & Gisel, E. (2009). Sensori-motor and daily living skills of preschool children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*(2), 231–241.

Kiresuk, T. J., Smith, A. E., & Cardillo, J. E. (1994). *Goal attainment scaling: Applications, theory, and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Mailloux, Z., May-Benson, T. A., Summers, C. A., Miller, L. J., Brett-Green, B., Burke, J. P., . . . Schoen, S. A. (2007). Goal Attainment Scaling as a measure of meaningful outcomes for children with sensory integration disorders. *American Journal of Occupational Therapy*, *61*(2), 254–259.

Mailloux, Z., Mulligan, S., Roley, S. S., Blanche, E., Cermak, S., Coleman, G. G., . . . Lane, C. J. (2011). Verification and clarification of patterns of sensory integrative dysfunction. *American Journal of Occupational Therapy*, *65*(2), 143–151. doi:10.5014/ajot.2011.000752

Miller, L. J., Coll, J. R., & Schoen, S. A. (2007). A randomized controlled pilot study of the effectiveness of occupational therapy for children with sensory processing disorder. *American Journal of Occupational Therapy*, *61*(2), 228–238.

Mulligan, S. (1998). Patterns of sensory integration dysfunction: A confirmatory factor analysis. *American Journal of Occupational Therapy*, *52*(10), 819–828.

Parham, L. D., Ecker, C., Kuhaneck, H. M., Henry, D. A., & Glennon, T. J. (2007). *Sensory Processing Measure manual*. Los Angeles, CA: Western Psychological Services.

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy*, *65*(1), 76–85. doi:10.5014/ajot.2011.09205

Ruble, L., McGrew, J. H., & Toland, M. D. (2012). Goal Attainment Scaling as an outcome measure in randomized controlled trials of psychosocial interventions in autism. *Journal of Autism and Developmental Disorders*, *42*(9), 1974–1983. doi:10.1007/s10803-012-1446-7

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., van Hooydonk, E., . . . Kendra, D. (2013). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders*, *44*(7), 1493–1506. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., & Case-Smith, J. (2014). Sensory interventions for children with autism. *Journal of Comparative Effectiveness Research*, *3*(3), 225–227.

Schaaf, R. C., & Mailloux, Z. (2015). *Clinician's guide for implementing Ayres Sensory Integration: Promoting participation for children with autism*. Bethesda, MD: AOTA Press.

Schaaf, R. C., Toth-Cohen, S., Johnson, S. L., Outten, G., & Benevides, T. W. (2011). The everyday routines of families of children with autism: Examining the impact of sensory processing difficulties on the family. *Autism*, *15*(3), 373–389.

Smith, S. A., Press, B., Koenig, K. P., & Kinnealey, M. (2005). Effects of sensory integration intervention on self-stimulating and self-injurious behaviors. *American Journal of Occupational Therapy*, *59*(4), 418–425.

CHAPTER 22

Viewing Intervention Through Different Lenses

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In all affairs it's a healthy thing now and then to hang a question mark on the things you have long taken for granted.

—Bertrand Russell

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Describe how clinical reasoning and evaluation and intervention decisions are shaped by the selection of a guiding frame of reference or theory.
- ✔ Consider that there is more than one approach that may be effective in intervention for children with sensory-integrative-based dyspraxia.
- ✔ Describe how the Cognitive Orientation to daily Occupational Performance (CO-OP) model may be applied to a child with sensory integration (SI) dysfunction.

Purpose and Scope

The lens through which a therapist views a child determines the look of the intervention. Similarly, the principles of a particular approach dictate the focus of the therapist's critical reasoning. Within the broad context of occupational therapy, there are multiple ways of thinking about children, conceptualizing their difficulties, and minimizing the effects of those difficulties. Although there may be approaches that are "wrong"—that is, they are known to be ineffective or they are not appropriate or feasible in a given situation—there are likely to be multiple "right" approaches to intervention. In most chapters, we use sensory integration (SI) theory to assess, interpret findings, and plan intervention. In this chapter, we view intervention for Lars, an 11-year-old boy referred for occupational therapy because of substantial difficulties performing many complex motor tasks through two equally plausible interventions. In the first instance, we describe Lars and his intervention using a modified sensory integrative approach. Then we change the frame and use the **Cognitive Orientation to daily Occupational Performance (CO-OP)** model, which, as the name suggests, is a cognitive problem-solving approach often used with children who have a diagnosis of developmental coordination disorder (DCD).

DCD is a neuromotor condition that, by definition, cannot be explained by intellectual disability or another neurological condition affecting movement (American Psychiatric Association, 2013). The difficulties of children with DCD are very similar to those of children diagnosed with dyspraxia. In fact, in cases where there is also a somatosensory or vestibular-proprioceptive processing disorder, a child might be diagnosed with either DCD or sensory-integrative-based dyspraxia, depending on the views and training of the professional making the diagnosis. Several researchers (Smits-Engelsman et al., 2013; Green, Chambers, & Sugden, 2008) have shown the effectiveness of the CO-OP Approach™.

Looking at Lars Through a Modified Sensory Integrative Lens

In this section, we view Lars through a sensory integrative lens. However, for several reasons, we modify some of the principles. Ayres (1972) proposed that sensory integrative therapy was a means of changing the underlying function of the central nervous system (CNS) in order to promote processing of sensation, which in turn led to improved body scheme and motor planning. In Ayres' (1972) words, "The objective is modification of the neurological dysfunction interfering with learning rather than attacking the symptoms of that dysfunction" (p. 2). She proposed that improved motor planning would result in better abilities to learn new motor tasks. But however powerful SI may be, it is neither a miracle nor a cure. Ayres (1972) went on, "This type of therapy . . . does not necessarily eliminate the need for the more symptomatic approach. Therapy is considered a supplement, not a substitute, to formal classroom instruction or tutoring. It reduces the severity of the difficulty and allows specifics . . . to be learned more rapidly" (p. 2). No doubt, the same could be said about learning to rapidly descend an open stairwell or ride a bike.

Because of the nature of Lars' problems, ascertained through testing and observation, we believe that a sensory integrative approach can be effective for ameliorating underlying difficulties and ultimately making it easier for him to learn new motor skills. But Lars is 11. He is interested in a very rapid solution to his goals. He is also enrolled in an intensive intervention program that occurred during 1 week. Working firmly within the philosophical base of occupational therapy, we set an explicit goal that we felt he could master in the four sessions. In keeping with sensory integrative therapy, we developed activities that captured Lars' intrinsic motivation to play and we incorporated ample opportunities for him to experience enhanced sensation, especially vestibular-proprioception, in the context of active engagement in the therapy. We adapted traditional sensory integrative therapy slightly to emphasize activities that "mimicked" aspects of the targeted goal.

The results of testing suggested that Lars had difficulty processing vestibular-proprioception, seen as poor postural-ocular control (i.e., difficulties with prone extension, neck flexion against gravity, equilibrium). Poor processing of vestibular-proprioception seemed to contribute to difficulties with bilateral integration and sequencing (BIS). Figure 22-1 shows the results of Lars' Sensory Integration and Praxis Test (SIPT) testing and clinical observations. We labeled his SI dysfunction as deficits in Vestibular Bilateral Integration and Sequencing (VBIS), a relatively mild form of dyspraxia. See also Chapter 5 (Praxis and Dyspraxia).

The first day of intervention, Lars and his mother set a goal of "descending a flight of open stairs reciprocally and without hesitation." The therapist then observed Lars going down the stairs. As she watched, she engaged in task analysis to develop specific hypotheses about the reasons for Lars' difficulty with the stairs. She videotaped his performance for comparison at the end of the intensive intervention. Lars descended the stairs slowly and in a step-tap fashion (i.e., without alternating feet). He looked downward, carefully monitoring his feet and the stairs. He held the railing securely, appearing fearful. Lars' performance on the stairs suggested that his proprioceptive processing deficits resulted in a poor sense of where his feet were in space and contributed to difficulties integrating the two sides of his body.

While Lars was still on the stairs, the therapist placed cuff weights around his ankles to test the hypothesis. However, rather than improving, Lars' performance actually deteriorated. In one more attempt to examine the theory of poor proprioception as a major contributor to impaired stair climbing, the therapist moved the weights to Lars' shoulders. This time the improvement was dramatic. Although he still held the handrail, Lars walked reciprocally and much more quickly down the stairs. We interpreted this "improved performance" as suggesting that weights on the shoulder provided resistance (i.e., proprioception) through the trunk and potentially all the way to the feet as when he was weightbearing. In contrast, weights on the feet yielded proprioception to a much more restricted area and were,

Visual	Score	Vestibular	Score	Somatosensory	Score	Interoception/ Sensory Modulation	Score
Visual Spatial		**Postural Control**		**Proprioception**			
SV	−0.50	SWB	−2.70	KIN	−3.00	Sensory responses	No concern
FG	+0.89	Prone extension	Weak	SWB	−2.70	Over/Under fluctuating	
		Stability	Poor	Poor body scheme	Yes		
Visual Praxis		Righting	Poor	Observations (e.g., finger/nose, thumb/finger touching, diadokokinesis)	Poor	SPM results	Home Scl
DC	−0.67	Equilibrium	Poor			Visual	OK OK
CPR	−0.90					Hearing	OK OK
MAC	−0.50	**Vestibular-Ocular**				Touch (LTS)	OK OK
Haptic Form and Space		Low PRN	−1.63			Body awareness	OK OK
		Ocular stability	Poor			Balance and motion	OK OK
MFP	+0.89	Head/neck/eye coordination	Poor	**Tactile**			
GRA	−0.90			LTS	−0.50		
		Summary	Poor	GRA	−0.90	SP2 results	NA
				FI	+1.20		
				MFP	+1.26		
Observations Able to complete age-appropriate puzzles with help organizing				Observations		Observations	
						Arousal	OK OK
						Affect	OK OK
						Activity level	OK OK
						Attention	Can be poor at times
		Bilateral Integration	**Score**	**Praxis**	**Score**		
		BMC	−1.80	PPr	+1.07		
		SPr	−2.80	OPr	+1.06		
		OPr	−0.99	PRVC	+1.20		
		GRA	−0.90	(SPr)	−2.80		
		MFPII	+1.10	(BMC)	−1.80		
		MAC	−0.50	Flexion	Poor esp. neck/ head		
		Observations e.g., skipping, jump jacks	Poor				

FIGURE 22-1 Lars' completed diagnostic worksheet.

therefore, not as effective for providing a sense of where Lars' body was in space.

Lars participated in intervention for 1 hour on each of the next 4 days. Intervention activities provided him with opportunities to take in enhanced vestibular-proprioception, through activities that provided resistance to movement and demanded BIS. The therapist created activities involving Lars' whole body but emphasizing his trunk and lower extremities. For example, while he was prone or supine in the net, Lars kicked off a mat leaning against a wall. He did the same thing on a scooter board. Lars also kicked large balls while swinging supine in the net. Because stair climbing is done in an upright position, he also engaged in jumping activities as well as challenging obstacle courses that he moved through as quickly as possible.

Lars co-created these activities with the therapist but she offered more context (e.g., emphasizing the lower extremities) than she might have done in typical sensory integrative therapy. Table 22-1 details the principles of intervention, drawn from Parham and colleagues' ASI Fidelity Measure (ASIFM) and applied to the four intervention sessions with Lars. As noted, the therapists modified sensory integrative therapy slightly to fit with the short, intensive intervention block. Although the therapist collaborated with Lars in activity choice (Principle 6 in Table 22-1), all activities involved enhanced proprioceptive input to the trunk and lower extremities, thus potentially restricting the available choice of activities.

At the end of the four sessions, the therapist took Lars back to the stairwell and once again videotaped his descent of the stairs, this time with no weights on Lars' shoulders. Just as Lars began the descent, someone handed him a cap, which he placed on his head. Then he ran quickly down the stairs, his hands in his pockets, looking toward, and smiling at, his mother, who stood at the bottom.

Discussion

Lars made significant gains in just 4 hours of intervention that occurred during the course of 1 week. The activities in which Lars engaged during intervention looked very similar to those

TABLE 22-1 Principles of ASI as Applied to Lars' Intervention

Sessions 1–4
GOAL: DESCEND A FLIGHT OF OPEN STAIRS RECIPROCALLY AND WITHOUT HESITATION
1. Therapist ensures physical safety of child. The therapist anticipates physical hazards and ensures that Lars is physically safe through judicious use of mats, well-constructed swings, and physical proximity.
2. Therapist presents sensory opportunities to the child. The therapist presents Lars with activities emphasizing enhanced vestibular and proprioceptive input to challenge postural-ocular control, bilateral integration, and praxis (especially sequencing of projected actions).
3. Therapist supports sensory modulation for maintaining a regulated state. The therapist modifies activity challenges to help Lars maintain optimal arousal and an affective state that supports engagement in activities.
4. Therapist challenges postural, ocular, oral, or bilateral motor control. Challenges are embedded in sensory-motor activities that challenge and build bilateral integration, strength, speed, and agility in static and dynamic postural control.
5. Therapist challenges praxis and organization of behavior. Challenges address Lars' ability to plan a novel sequence of movements related to descending the stairs.
6. Therapist collaborates with child in activity choice. The therapist negotiates activity choices with Lars such that he can see that the activities have a clear relationship to descending the stairs. The therapist provides structuring and support while maximizing Lars' active control.
7. Therapist tailors the activity to present a just right challenge. The therapist presents challenges that are not too difficult or too easy for Lars.
8. Therapist ensures that activities are successful. The therapist supports Lars' experience of success in doing part or all of an activity.
9. Therapist supports the child's intrinsic motivation to play. The therapist creates a setting that supports play that reflects his age as a way to fully engage Lars in intervention activities.
10. Therapist establishes a therapeutic alliance with the child. The therapist promotes and establishes a connection with Lars that conveys they are working together in a mutually enjoyable partnership. Overall, there is a climate of trust, emotional safety, connectedness, and appreciation of Lars as a person.

one would see in any clinic that uses sensory integrative therapy. The differences lay in the emphasis of the intervention activities on providing enhanced sensation to particular body parts. In addition to addressing a larger goal of improving SI, the therapist was guided by the demands of stair climbing and a belief that what interfered with Lars' mastery of the stairs was poor processing of vestibular and proprioceptive sensations contributing to difficulties with VBIS. Because of the demands of stair climbing on coordinated use of the lower extremities and trunk, the therapist made sure to emphasize those body parts in the creation of activities that provided enhanced proprioception and demanded bilateral projected action sequences. She did not include stair climbing as an activity.

Several things remain unknown about the effects of Lars' intervention. First, it is possible that Lars secretly spent a portion of each day practicing stair climbing at home and that this, in fact, was responsible for his gains. Second, nothing is known about whether Lars' SI actually improved. However, given current theories about CNS functioning and SI, it seems quite possible that they did. Finally, we do not know to what extent Lars remained able to descend the stairs after some time passed. In other words, were Lars' gains sustainable? If they were not, we would conclude that SI had not improved because of that short-term intervention.

If Lars had been seen in a more typical clinical situation rather than in the short intensive intervention, the therapist would have met again with him and his mother to see if there were additional goals that he wished to address—perhaps bike riding.

If Lars *had* set a goal for bike riding, the therapist would have begun by observing him attempting to ride his bike. She would have analyzed the ways in which poor VBIS, posture, and other indicators of poor SI interfered. The activities she co-created with Lars to meet a bike riding goal would have looked quite different from those that promoted descent of the staircase, instead challenging sitting balance and coordinated, anticipatory bilateral use of his upper extremities. Because of a similarity of body position and demand for postural adjustment with bike riding, the therapist might plan several activities in which Lars sat on the bolster swing, scooter board, or a large ball. Hitting a moving target with the bolster swing that he was propelling by pulling on handles might be an example. Similarly, he might sit cross-legged on the scooter board, holding a hoop while the therapist, holding the other side of the hoop, pulled him in large orbits around her. He could maintain his balance while sitting cross-legged on a large ball and hitting tossed balls or beanbags back to the therapist.

HERE'S THE POINT

- Lars, a child diagnosed with VBIS, engaged in an intense, short-term intervention based on a modified SI approach. The result was a dramatic improvement in his ability to descend an open stairwell.
- Intervention involved activities that provided opportunities for him to take in enhanced sensation, especially vestibular-proprioception, in the context of active engagement. The traditional approach to SI was modified so that activities "mimicked" aspects of the targeted functional goal.

The CO-OP Approach™

Rather than focusing on potential impairments in praxis or sensory modulation, therapists using the CO-OP approach consider breakdowns in task performance, regardless of the cause, and incorporate meta-cognitive problem-solving to guide children to discover strategies that enable them to reach functional goals (Polatajko & Mandich, 2004). Embedded in the philosophical base of occupational therapy, many of the objectives are the same as those that would respond to sensory integrative treatment, but the techniques for meeting the goals and the underlying assumptions differ markedly.

The CO-OP process is as follows. The child commonly identifies three or four goals. Meeting each goal generally requires between one and three sessions with practice outside the sessions. Goals are explicit and meaningful to the child and family. The clinician uses **dynamic performance analysis (DPA)** to identify where the task is breaking down.

The focus of the intervention is on identifying cognitive strategies to facilitate learning motor skills. **Guided discovery** techniques enable children to solve functional problems (Polatajko, Mandich, & Martini, 2000). Children learn a global problem-solving strategy, **Goal-Plan-Do-Check.** They are encouraged to identify **domain-specific strategies (DSSs)** to solve performance problems and learn how, when, and where to use the specific DSSs to support generalization and skill transfer (Martini, Mandich, & Green, 2014).

Enabling principles and guided discovery promote learning by engaging the child to overcome task performance breakdowns and work toward independence (Missiuna, Mandich, Polatajko, & Malloy-Miller, 2000; Polatajko & Mandich, 2004; Polatajko, Mandich, Miller, & Macnab, 2000; Polatajko, Mandich, Missiuna, et al., 2000). Intervention is concluded with successful task achievement. Arguably, however, therapists might wish to consider additional outcomes and establish whether children can independently engage in successful strategy generation before intervention terminates, to support skill transfer to new, unlearned tasks.

Looking at Lars Through the CO-OP Approach™ Lens

When we consider Lars through a CO-OP lens, we think of him only as having difficulty with complex motor tasks. We do not worry about the source of the difficulty.

Lars selects a goal and then proceeds, together with the therapist, through the Plan-Do-Check phases. Lars and his mother identified the goal of "descending a flight of open stairs reciprocally and without hesitation." The therapist then identified what **task knowledge** Lars had with regard to the goal (i.e., does he know how to do it?). Then she observed him performing the task. Lars understood that he needed to place one foot on a step and then the other foot on the next step down. DPA allowed the therapist to identify that Lars placed each foot on different parts of the step, seemingly at random, and sometimes with his toes over the edge. As he took a step, he sometimes leaned forward, looking at his feet, and sometimes he leaned back. Leaning back appeared to coincide with his feet slipping and it was then that he reported being frightened of falling.

Utilizing enabling principles that focused attention to the task in a fun and engaging manner, and using modelling and questioning, the therapist supported Lars in the guided discovery of where he was placing his feet on the stairs and in devising a plan. His first plan involved placing his feet on the middle of each step. Lars then undertook the "Do" phase of Goal-Plan-Do-Check. He practiced going up the bottom three steps and then back down. Doing was followed by "Check" to review performance. Lars recognized that he still leaned forward to see his feet. He wanted more practice so that he could place his feet without looking down and still really "know when all his toes were touching the step." His homework was to practice placing his feet in the middle of the bottom three steps at home, going up and down, and reflect on strategies he used to "know when he was in the middle of the step" without looking.

On return to the clinic the following week, having mastered placing his feet in the middle of the step, Lars then identified that he slipped when he leaned backwards because his body was not "holding his feet down on the step." His new plan was to walk upright with a piece of paper on his head to get the feeling of how it was to be "straight as if a tower." His next plan involved going up and down the bottom three steps. Checking out whether this worked, Lars identified that as long as he executed both plans (i.e., foot in middle, walking tall as if a tower), he could go up and down steps, placing his feet on alternate stairs, without fear of falling. Homework involved practicing going up and down more steps so that both his plans became associated with climbing up and down stairs. Lars' goals were achieved across two sessions within the stairwell at the clinic. The next goal was to achieve the full flight of steps in an open stairwell. Table 22-2 describes the Goal-Plan-Do-Check cycles associated with Lars' two CO-OP sessions.

Discussion

Lars managed to achieve his goal of going up and down stairs using alternate feet having identified that he did not always place his feet in the middle of the step and that if he looked at his feet, and especially if he leaned back, he had more of a chance of falling. The process of identifying where the task was breaking down and developing specific strategies to solve the problems

TABLE 22-2 CO-OP Goal-Plan-Do-Check Phases Associated with Each Intervention Session

	SESSION 1 (WEEK 1)	SESSION 2 (WEEK 2)
Goal: What do I want to do?	Descend a flight of open stairs reciprocally and without hesitation	
Plan: How am I going to do it?	Using careful placement of each foot on the middle of each step	Walk up and down the stairs with a piece of paper on his head
Do: Carry out the plan	Practice going up and down the bottom three steps and reflect on the strategies to know when his foot was in the middle of the step without looking	Practice going up and down several steps, with his foot in the middle, without looking, walking tall as if a tower
Check: How well did my plan work?	Lars slipped when he leaned backward because his body was not "holding his feet down on the step."	Success!

HERE'S THE EVIDENCE

The CO-OP approach has been shown to be effective for improving the functional problems of children with motor coordination problems. A study by Taylor, Fayed, and Mandich (2007) used a single subject research design with four children from 5 to 7 years of age to examine the effectiveness of using the CO-OP. Based on Canadian Occupational Performance Measure ratings and performance observation ratings following intervention, these researchers demonstrated the effectiveness of the CO-OP approach for addressing goal achievement in young children with motor deficits. A 2010 systematic review of non-sensory interventions (Polatajko & Cantin, 2010) also included CO-OP.

enabled Lars to make significant achievements with this particular goal. The homework tasks provided opportunities to try out his strategy repeatedly in different contexts.

Lars wanted to set another goal (task). The second goal would not only put another skill in place but would also reinforce his use of the global strategy of Goal-Plan-Do-Check. The hope was that the more times he used the process, the more spontaneously he would use it in the future when he encountered difficult tasks. The therapist was instrumental in guiding Lars to analyze his performance, compare it with what was needed for success, and reflect on problems.

Second Goal: Bike Riding

Although Lars wanted to ride his bike, Lars indicated that he never mastered riding with training wheels (stabilizers) and did not want to learn with them now—at 11 years of age. The therapist determined Lars' knowledge of the task: He knew he had to sit on the bike seat, hold the handle bars, and push the pedals. During the DPA to ascertain where the task was breaking down, it was clear that Lars did not know which way to lean for the initial push off, did not steer in the direction he wished to go, and did not know what to do when he wanted to stop. The therapist worked with Lars to devise his plans. Generally, therapists using the CO-OP recommend working on only one strategy (plan) at any one time. In this instance, however, the therapist felt that both starting and stopping could be addressed simultaneously, so they developed two plans. Using enabling principles and guided discovery, Lars identified that he did not need to lean into the foot he placed on the pedal when mounting the bike but rather "push forward on the pedal." He also figured out that when he wished to stop, he needed to put both feet on the ground. (This was based on the premise that he would not be cycling too fast at the beginning.) Because two DSSs were developed (i.e., "how the body feels when push starting" and "attention to task": putting both feet on the ground to stop), Lars and the therapist engaged in several practice "Do" stages to check whether he had done one or the other, or both strategies. Therefore, Lars realized that he also needed to "point the handle bars in the direction he wanted to go." He achieved all this in the first session, although there was little time to practice the final strategy, so this was set as a homework task.

On return to the clinic the following week, Lars had mastered the strategies but also realized he was only able to cycle in a straight line and on a flat surface. That meant he could not "cycle with his friends" as this required cycling on uneven surfaces, changing directions, and avoiding obstacles. The therapist worked with Lars to identify what was different about cycling in a straight line on an even surface and what he might need to do on uneven surfaces. They considered strategies, such as "holding tight" or "bouncing a bit on the seat." They set homework tasks for Lars to try out these strategies and identify which worked best for him. The importance of homework tasks and the need for feedback from a "significant other" (one of Lars' parents) required the therapist to teach a parent the key principles of CO-OP. This essential aspect of CO-OP helps to ensure generalization of its use across contexts and tasks.

HERE'S THE POINT

- The CO-OP approach differs markedly from SI in that it applies a cognitive, problem-solving approach focused on learning a desired functional skill, rather than on remediating underlying deficits that may be contributing to performance problems.
- The CO-OP model applies task- and context-specific strategies to assist a child in meeting targeted goals.

- When Lars engaged in CO-OP to meet his goals, he and the therapist analyzed what went wrong when he tried to descend the stairs or ride his bicycle. They developed strategies to change the way he performed the tasks. Lars practiced using the new strategies and worked together with the therapist to modify the strategies as needed until he was successful.

Summary and Conclusions

In this chapter, we compared a modified SI therapy approach with that of the CO-OP approach by illustrating how each might look with the same 11-year-old boy whose goals were to descend an open stairwell reciprocally and without hesitation and to ride a two-wheeled bike independently. There are many possible approaches to intervention for children with difficulties mastering complex motor tasks. The "best" approach for any particular child will be the one that is most appropriate and feasible in the situation and that results in successful goal achievement.

Where Can I Find More?

The CO-OP Academy website: http://ot.utoronto.ca/coop/index.htm

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Association.

Ayres, A. J. (1972). *Sensory integration and learning disorders.* Los Angeles, CA: Western Psychological Services.

Green, D., Chambers, M., & Sugden, D. (2008). Does subtype of developmental coordination disorder count: Is there a differential effect on outcome following intervention? *Human Movement Science, 27*(2), 363–382.

Martini, R., Mandich, A., & Green, D. (2014). Implementing a modified cognitive orientation to daily occupational performance approach for use in a group format. *British Journal of Occupational Therapy, 77*(4), 214–219. doi:10.4276/030802214X13968769798917

Missiuna, C., Mandich, A., Polatajko, H., & Malloy-Miller, T. (2000). Cognition Orientation to Daily Occupational Performance (CO-OP): Part I—theoretical foundations. *Physical & Occupational Therapy in Pediatrics, 20*(2/3), 69–81.

Polatajko, H. J., & Cantin, N. (2010). Exploring the effectiveness of occupational therapy interventions, other than the sensory integration approach, with children and adolescents experiencing difficulty processing and integrating sensory information. *American Journal of Occupational Therapy, 64,* 415–429.

Polatajko, H. J., & Mandich, A. (2004). *Enabling occupation in children: The Cognitive Orientation to daily Occupational Performance (CO-OP) approach.* Ottawa, ON: Canadian Association of Occupational Therapists.

Polatajko, H. J., Mandich, A., & Martini, R. (2000). Dynamic performance analysis: A framework for understanding occupational performance. *American Journal of Occupational Therapy, 54*(1), 65–72.

Polatajko, H., Mandich, A., Miller, L., & Macnab, J. (2000). Cognitive Orientation to daily Occupational Performance (CO-OP): Part II—the evidence. *Physical & Occupational Therapy in Pediatrics, 20*(2/3), 83–106.

Polatajko, H., Mandich, A., Missiuna, C., Miller, L., Macnab, J., Malloy-Miller, T., & Kinsella, E. (2000). Cognitive Orientation to daily Occupational Performance (CO-OP): Part III—the protocol in brief. *Physical & Occupational Therapy in Pediatrics, 20*(2/3), 107–123.

Smits-Engelsman, B. C., Blank, R., Van Der Kaay, A.-C., Mosterd-Van der Meijs, R., Vlugt-Van Den Brand, E., . . . Wilson P.H. (2013). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: A combined systematic review and meta-analysis. *Developmental Medicine and Child Neurology, 55,* 229–237.

Taylor, S., Fayed, N., & Mandich, A. (2007). CO-OP intervention for young children with developmental coordination disorder. *OTJR: Occupation, Participation and Health, 27*(4), 124–130.

CHAPTER 23

Is Sensory Integration Effective? A Complicated Question to End the Book

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A fool's brain digests philosophy into folly, science into superstition, and art into pedantry.

—George Bernard Shaw

LEARNING OUTCOMES

Upon completion of this chapter, the reader will be able to:

- ✔ Understand four facets contributing to the question of effectiveness:
  - ✔ The state of the scientific foundation underlying sensory integration (SI) theory
  - ✔ The contribution of art
  - ✔ The chaos of effectiveness
  - ✔ The place of SI in occupational therapy intervention

Purpose and Scope

Sensory integration (SI) is a theory, a practice framework, and a foundation for reasoning. Arguably, it is the most complex theory and practice framework in occupational therapy. SI has given rise to more research and, undoubtedly, stirred more controversy than any other in occupational therapy. Seemingly, everyone has an opinion on whether or not it works.

In 2012, the American Academy of Pediatrics (AAP) published a position statement indicating that "Occupational therapy with the use of sensory-based therapies may be acceptable as one of the *components of a comprehensive treatment plan."* The AAP qualified their statement by saying that the research is limited and families must learn how to evaluate the effectiveness of intervention. Of course, that statement is true of all occupational therapy interventions.

However, when Rodger, Ashburner, and Hinder (2012) responded to the AAP position statement in an invited editorial in the *Australian Journal of Occupational Therapy,* they indicated that, "by continuing to practise and promote interventions that are poorly supported by evidence [i.e., sensory integration], we are doing our clients, ourselves and our profession a disservice" (p. 337). Such a negative and narrow stance by powerful therapists only fuels division in the profession, especially when their argument is based "more in truisms that apply to all occupational therapy interventions than in evidence about SI":

> (i) Unclear terminology causes confusion; (ii) Occupational therapists have a responsibility to investigate [the effectiveness of interventions they provide to children and families]; (iii) Occupational therapists must articulate their reasoning [in recommending

> particular interventions]; (iv) Supporting families to make informed decisions is important; and (v) Occupational therapy is more than the approaches that therapists use. (Bundy et al., 2013, p. 221)

Rodger and colleagues (2013) also criticized the cost of sensory integrative therapy, reflecting on the time required to effect the desired changes. "As reported, intervention frequencies vary from 1 to 5 weekly sessions for 2–8 months (May-Benson & Koomar, 2010), the financial and time costs can be prohibitive for many families." (p. 223)

Beyond the time commitments, cost, and issues that apply to all occupational therapy, the question of effectiveness of SI is complex and, indeed, requires further research. In this chapter, we discuss inter-related facets that contribute to difficulty in answering the question, "Does sensory integration work?" We describe the difficulties of establishing central nervous system (CNS) change from therapy, an underlying assumption of the theory and a problem that plagues many professions. We focus on the need to be faithful to the whole of sensory integrative therapy (i.e., both the art and the science) when studying its effectiveness. We examine consequences that seem to have come from sacrificing art and focusing only on science in effectiveness research. We make a plea for goal-driven therapy and effectiveness research that targets logical and meaningful outcomes. Finally, because SI is only one aspect of occupational therapy, we revisit its place in the overall intervention process.

HERE'S THE EVIDENCE

This systematic review examined five studies that looked at SI therapy and an additional 14 that focused on sensory-based interventions. Interestingly, although the studies that examined SI therapy indicated positive outcomes, those looking at sensory-based interventions found minimal effects.

Case-Smith, J., Weaver, L. L., & Fristad, M. A. (2014). A systematic review of sensory processing interventions for children with autism spectrum disorders. *Autism, 19*(2), 133–48. doi:10.1177/1362361313517762

Sensory Integration as Science

Ayres (1972) indicated, "The objective [of sensory integrative therapy] is modification of the neurological dysfunction . . . rather than attacking the symptoms of that dysfunction" (p. 2). In other words, sensory integrative therapy is meant to improve processing and integration of sensation in the CNS. Thus, inevitably, the question associated with the science of SI theory comes down to the evidence for neurological differences in children and adults with sensory integrative dysfunction and whether intervention actually changes CNS processing. In recent years, many investigators have put considerable resources into finding links between behavior and neural processes, focusing particularly on sensory responsivity. (See also Chapter 15, Advances in Sensory Integration Research: Clinically Based Research, and Chapter 16, Advances in Sensory Integration Research: Basic Science Research, respectively.) However, although there is some indication that SI dysfunction is associated with autonomic nervous system differences (Lane, Reynolds, & Thacker, 2010; Mangeot et al., 2001; McIntosh, Miller, Shyu, & Dunn, 1999; Miller, McIntosh, Shyu, & Hagerman, 1999; Miller, Nielsen, & Schoen, 2012; Schaaf et al., 2010; Schaaf, Miller, Sewell, & O'Keefe, 2003; Schoen, Miller, Brett-Green, & Nielsen, 2009), as well as structural differences (Chang et al., 2014; Owen et al., 2013), unequivocal conclusions remain elusive. Further, current tools do not provide the answers that we seek to test the underlying assumptions related to neuroplasticity and intervention. As such, we assume some relationships between SI and the CNS. We have, however, found support that provides a scaffold to these assumptions in work outside the field of SI and generally outside the field of occupational therapy (Lane & Schaaf, 2010).

To link change to intervention, therapists and theorists extrapolate from animal studies of sensory application and enriched environments for a theoretical foundation. (See Chapter 16, Advances in Sensory Integration Research: Basic Science Research, for detailed information.) Lane and Schaaf (2010), in a systematic review of literature underpinning sensory integrative therapy, indicated that available literature (1) examines the effects of environmental enrichment (similar to that found in a well-equipped SI clinic) and of providing direct sensory input, and (2) documents resulting changes in neural structure and function as well as behavior. Neuroscientists have uncovered a great deal about the interactions between sensation and function—perceptual, motor, behavioral, and emotional. We use this information to support new scientific assumptions, most of which are consistent with what Ayres postulated so long ago. And, as a logical extension, our approach to children in intervention remains remarkably similar to that which Ayres developed.

Scores of researchers have examined "sensory-based" interventions involving single-domain sensory inputs. These include techniques such as weighted vests and Therapressure Program protocols that are sometimes used within sensory integrative therapy sessions or as the basis for home programs or coaching interventions for children with sensory integrative dysfunction (e.g., Buckle, Franzsen, & Bester, 2011; Cox, Gast, Luscre, & Ayres, 2009; Fertel-Daly, Bedell, & Hinojosa, 2001; Hodgetts, Magill-Evans, & Misiaszek, 2010a, 2010b; Kane, Luiselli, Dearborn, & Young, 2004; Lee & Song, 2015; Leew, Stein, & Gibbard, 2010; Lin, Lee, Chang, & Hong, 2014; Mullen, Champagne, Krishnamurty, Dickson, & Gao, 2008; Murdock, Dantzler, Walker, & Wood, 2013; Reichow, Barton, Sewell, Good, & Wolery, 2010; Vandenberg, 2001). See also Chapter 17 (Using Sensory Integration Theory in Coaching). Although these interventions do *not* meet the criteria for sensory integrative therapy, they share common sensory roots and are, therefore, related. Perhaps unsurprisingly and for reasons we discuss later in the chapter, the outcomes (e.g., on-task behavior, attention, reduced stereotypies) of these, mostly small, studies have been inconclusive. (See also Chapter 17, Using Sensory Integration Theory in Coaching.)

The bottom line with regard to the science is that researchers working to identify and understand CNS links to behavior, in general, and changes in central processing because of therapy, in particular, have provided insights but no clear answers. Thus, therapists and theorists rely on hypotheses. However, occupational therapy is not alone in this space. Researchers in other fields, including, for example, psychotherapy, also face challenges when examining CNS parameters that might explain behavioral differences. Interestingly, many of the hypothesized neural links between sensation and behavior on which Ayres based her original work continue to stand. So, although the jury is still out, the most current neurological evidence continues to support sensory integrative therapy as a viable approach to intervention. And, to be fair, although Ayres (1972) believed that therapy results in neurological change, she did not claim that it *eliminated the underlying causes of* . . . learning disorders. Rather, she said that it "*mitigated some of the conditions* . . . *that directly interfere with learning* . . . [and that it came closer to] altering the neurologic dysfunction . . . than . . . typical academic procedures" (p. 2; italics added).

HERE'S THE POINT

- Current research directly examining the building blocks of SI has produced equivocal findings; thus, just looking at the building blocks is not sufficient to understand the influence of sensory integrative intervention on function.
- The jury is still out with regard to the CNS underpinnings of sensory integrative dysfunction and CNS changes that occur because of intervention.
- Developing neuroscience knowledge, largely from animal and adult human studies, continues to support Ayres' early assumptions about the link between brain and behavior.

The Art of Therapy

Ayres began developing SI theory in an era when occupational therapy had moved from its original emphasis on occupation to a focus on the mechanisms that supported function and created dysfunction. Thus, for Ayres in the 1960s, understanding the neuroscience underpinnings of dysfunction was of paramount importance. Nonetheless, Ayres always kept one foot in the clinical world, looking to find answers to the problems faced by her clients. (See also Chapter 3, Composing a Theory: An Historical Perspective.)

The "mechanistic paradigm" that characterized the focus of occupational therapy when Ayres began her work continued well into the 1970s (Kielhofner, 2009). With regard to SI theory, it seems to have continued much longer—arguably well into the 1990s. In concentrating on the scientific foundations of SI, occupational therapy researchers perhaps focused too much on studying the scientific building blocks, without remembering Ayres' insights into the art of therapy.

Peloquin (2005) likened the partnership of art and science to "grains of sand and waves of sea [that] together make seaside." She went on to say that "Seaside would not *be* if [either sand or waves] were gone" (p. 619). "Effective practice is artistry and science" together (Peloquin, 2005, p. 613). Perhaps that partnership is even more true in sensory integrative therapy than in other occupational therapy interventions.

Science allows therapists to associate enhanced sensation with the most logical proximal objectives (e.g., vestibular with posture; tactile, vestibular, proprioception with praxis). Art allows therapists to adapt therapeutic activity continually to meet the moment-by-moment needs of a child (Peloquin, 1989, 1998). Whereas science gives SI credibility, art gives it meaning. As in all good partnerships, the relationship between art and science is fluid. One may predominate for a time, but both make equal contributions in the long run. (See also Chapter 12, The Art of Therapy, and Chapter 13, The Science of Intervention: Creating Direct Intervention from Theory.)

Intervention based on the principles of SI looks similar to play. And it *is* a special kind of play that weaves art and science together. The "play" always involves enhanced sensation, meaningful activity, and a skilled therapist-playmate. The Ayres Sensory Integration© Fidelity Measure (ASIFM; Parham et al., 2011) validates the association of play with the building blocks that comprise the science of SI theory. But when we were writing the first edition of this text, Ayres cautioned us about equating intervention with play. She feared that an explicit association between play and SI theory would denigrate the science of the theory. However, Ayres was working in a different time.

The power of the play that occurs between a skilled therapist and a child is undeniable. Ayres herself was a master at therapeutic play. She knew intuitively how to partner art with science and when to slide between the two. Although the values of the era may not have allowed her to admit it, Ayres seemed to feel that even though science was the root of therapy, play provided an irresistible invitation for children to become involved. In other words, therapy without art is "the application of scientific knowledge in a sterile vacuum" (Mosey, 1981, cited in Peloquin, 1989, p. 220). Most children, wisely, are unwilling to enter a vacuum.

Play as therapy presents other difficulties that we would be remiss not to address. Play is, by definition, determined by the player. Intrinsic motivation (i.e., engaging in activity because you want to) and internal control (i.e., feeling in charge) are primary characteristics of play. Ayres (1972) called therapy "self-directed." Ayres qualified the notion of self-direction, saying, "Free play does not inevitably, in itself, further sensory integration, but too rigid [a] structure will inhibit the manifestation of potential. . . . Structure may push the child further toward the [proximal or scientific] objective than he can reach alone but too much will defeat its purpose" (p. 259).

Children in need of sensory integrative therapy have difficulty organizing actions and interacting effectively with other people, on objects, and in the environment. They need a therapist-playmate to provide underlying structure without taking away the child's feelings of control. Ayres (1972) called this "freedom within structure" (p. 258) and said that it is indispensable to therapeutic gain. "The kind of involvement necessary [for] the child becomes effectively self-directing . . . cannot be commanded; it must be elicited" (p. 259). She was, however, also clear that the ability to create freedom within structure comes from a deep understanding of the science.

HERE'S THE POINT

- The art of sensory integrative intervention supports the therapist's ability to fluidly apply and adapt knowledge grounded in the scientific foundation.
- A major tenet of SI is that it supports the child's *play.* Artful SI therapy relies on the presence of a therapist-playmate with a strong foundation in the science of SI, an understanding of the art involved in each treatment session, and knowledge of how to embed intervention within meaningful activity and occupation.

The Challenge of Finding Effectiveness

Ayres left an indelible mark on occupational therapy. In her relatively short life, she created a theory based firmly in neuroscience, developed assessments to measure the theoretical constructs and test their relationships, shaped an intervention based in science and art, and implemented preliminary research to test the effectiveness of that intervention.

When Ayres studied intervention effectiveness, she studied sensory integrative therapy in its entirety: both art and science. She asked whether children's skills improved because of the full package. She did not dissect the intervention and test only the science. And her quest was successful. For example, compared with a control group, Ayres found greater increases in reading scores in children with generalized dysfunction and children with auditory-language dysfunction because of sensory integrative therapy.

Ayres was not the only one to demonstrate effectiveness of sensory integrative therapy. In an early meta-analysis, Ottenbacher (1982) concluded that sensory integrative therapy was effective in the remediation of motor, academic, and language functions, with the most improvements noted in the motor area. Specifically, in relation to children with learning disabilities, he reported that, "the average learning disabled student receiving sensory integration therapy performed better than 75.2 percent of the learning disabled subjects not receiving therapy" (Ottenbacher, 1982, p. 576). However, Ottenbacher included studies *only* between 1972 and 1981.

In 1999, Vargas and Camilli published a second meta-analysis. Although they found similar results to Ottenbacher's in the same time period (1972 to 1981), they failed to find evidence of effectiveness in the following decade. Why the difference? To borrow a phrase from *Alice-in-Wonderland,* "curiouser and curiouser."

Several factors may help to explain Vargas and Camilli's (1999) results. Not the least of these may be changes to the nature of the interventions employed in the studies that Vargas and Camilli (1999) included in their analysis. In an attempt to make their research more "scientific," researchers in that decade apparently felt the need to dissect their interventions in order to operationalize them. Thus, for example, Polatajko and colleagues (1991) compared the effects of SI therapy with perceptual motor therapy. In order to avoid contamination of the two approaches, they created a manual containing activities associated with each approach. Therapists were restricted to activities outlined in the manual. The unfortunate fact is that much of the research that Vargas and Camilli cited in their later studies (1982 to 1993) seems to have sacrificed art to preserve science. Perhaps unsurprisingly, they found only minimal effectiveness.

SI therapy is both art and science. In attempting a systematic review of research evaluating the effectiveness of sensory integrative therapy, Parham and colleagues (2007) found little evidence of fidelity to the principles of sensory integrative theory in 61 studies they reviewed to 2004. This led them to develop the ASIFM. The ASIFM promoted a return to sensory integrative therapy in its entirety: art and science. And with the return to SI as a whole, we have begun to see a return to the evidence for effectiveness. For example, Schaaf and colleagues (2014) found significant differences between control (usual care) and intervention groups on Goal Attainment Scaling (GAS), measures of caregiver assistance in self-care, and socialization.

In addition to problems with fidelity to the intervention, Vargas and Camilli (1999) reported another fact that may contribute to understanding effectiveness research. As though they were engaged in a fishing expedition, many of the researchers cited in the systematic review included an inordinate number of outcome measures that represented an inordinate number of categories (i.e., behavior, language, psychoeducational, motor or sensory-perceptual). Interestingly, Vargas and Camilli (1999) found that studies with four or fewer outcome measures, and those that measured effectiveness in only one dependent category, had significantly greater effect sizes than studies that included more outcome measures or measures from a greater number of categories. In other words, the greater the focus on specific outcomes, the more effective the therapy.

Although increasing the number of outcome measures or categories may seem to be one way of increasing the reliability of a study (Vargas & Camilli, 1999), intervention must be goal-directed to be maximally effective. How would a therapist know how to plan intervention directed at improving outcomes in up to five overarching categories? Put another way, how would an intervention be that was designed to improve simultaneously the psychoeducational, behavioral, language, motor, and sensory-perceptual performance of a child?

Several researchers (e.g., Cohn & Cermak, 1998; Parham et al., 2007) expressed related concerns about the appropriateness of outcome measures. Cohn and Cermak (1998, p. 540) indicated: The outcome assessments we choose implicitly display our belief systems and the underlying assumptions regarding the behaviors we hope to change. In practice, the assessment tools and the variables measured often become the operational definition for the changes we are attempting to measure (Haley, 1994).

Cohn and Cermak (1998) continued: "By focusing primarily on the underlying components of performance of children, occupational therapists have neglected to explore how sensory integration affects the everyday occupation of children in the context of their families" (p. 540).

Errors in establishing the most appropriate outcome measures may well have impaired the establishment of effectiveness of sensory integrative therapy. Addressing the concerns of Cohn and Cermak (1998); recent researchers (e.g., Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011; Schaaf & Mailloux, 2015); and theorists, researchers, and practitioners (Miller, Appendix A, this text) have advocated GAS (e.g., Kirusek & Sherman, 1968) as a means of capturing and ameliorating the everyday concerns that bring children to therapy.

Granted, SI is a neurological process underlying higher-order functions. And even though, at another point in time, sensory integrative therapy focused almost exclusively on body structure and function outcomes (e.g., bilateral coordination, balance), times have changed. Occupational therapy as a profession has returned to its occupation roots (Kielhofner, 2009). Acknowledging both the neural underpinnings and the primary goal to increase participation, Schaaf & Mailloux, (2015) described both proximal (i.e., body structure and function) and distal (i.e., participation) objectives as outcome measures in their randomized controlled trial. And they found effectiveness. In a rigorous systematic review, Schoen et al. (2019) established the effectiveness of ASI for children with autism based on a review of three studies (Iwanaga, et al., 2014, Pfeiffer, et al., 2011; Schaaf, et al., 2013). All found greater improvements in children receiving ASI than in the comparison groups. While the effect size in the Iwanaga et al. study (using the Japanese Miller Assessment for Preschoolers [Tsuchida, Sato, Yamada, & Matsushita, 1989] fell just below the ideal cutoff for best evidence, the other studies (using GAS goals and standardized measures) met or exceeded the criteria. This is an important finding, but more research is needed.

HERE'S THE POINT

- Early effectiveness studies examined the art *and* the science of SI intervention and concluded that this approach was successful in improving motor skills in children. Subsequent studies, focused on the science and controlling many factors in intervention, failed to show consistent treatment effectiveness.
- The failure to find positive treatment effects following SI intervention might be attributable to a lack of fidelity to the core principles of SI theory; many studies fall prey to this concern.
- The failure to find positive treatment effects following SI intervention might also be attributable to errors in establishing the most appropriate outcome measure.

PRACTICE WISDOM

These articles describe the process of SI intervention, examining therapist-child interactions and behaviors through the beginning and middle of a therapy session. Authors examined the patterns of therapist-child interaction and addressed the behaviors that reflect work and those that reflect play for both the child and the therapist. They provide an excellent description of how a therapist manages the complexity of SI intervention.

Dunkerley, E., Tickle-Degnen, L., & Coster, W. J. (1997). Therapist-child interaction in the middle minutes of sensory integration treatment. *American Journal of Occupational Therapy, 51*(10), 799–805.

Tickle-Degnen, L., & Coster, W. (1995). Therapeutic interaction and the management of challenge during the beginning minutes of sensory integration treatment. *Occupational Therapy Journal of Research, 15,* 122–141.

Sensory Integration as Part of Occupational Therapy

In embracing SI theory and sensory integrative therapy, we must be certain to situate ourselves within the broader realm of occupational therapy (Schaaf & Mailloux, 2015). Sensory integrative concerns are only one factor influencing occupational participation, engagement, and choices. (See also Chapter 2, Sensory Integration in Everyday Life.) Although SI can be, and is, often used in a classic manner, as a singular and specialized approach in private practices and outpatient clinics, SI is not the only trick in the occupational therapy bag.

However powerful SI may be, it is neither a miracle nor a cure. In fact, Ayres (1972) indicated, "This type of therapy . . . does not necessarily eliminate the need for the more symptomatic approach. Therapy is considered a supplement, not a substitute, to formal classroom instruction or tutoring. It reduces the severity of the difficulty and allows specifics . . . to be learned more rapidly" (p. 2).

Some practitioners have adopted the use of "Complementary Approaches" in their practice. Many of these approaches utilize the same science-based building blocks as SI theory. For example, programs such as Therapeutic Listening® are based on the neuroscience of the auditory system, the intimate interconnections between auditory and vestibular systems, the influence sound has on orienting to environmental change, and links between rhythmic sound input and motor output. The use of the Therapressure Program as one component of working with children with sensory defensiveness is based on the science underlying the somatosensory system, the transmission of tactile stimuli over different fiber pathways, the influence these inputs have on arousal, and the integration of somatosensory inputs with other sensory inputs (e.g., vestibular, visual; see also Chapter 18, Complementary Programs for Intervention). These approaches rely on structured protocols; outcomes are generally proximal skills (e.g., improved postural control or sensory responsivity). As such, although they may be very useful in addressing some of the concerns experienced by children with sensory integrative dysfunction, they generally do not focus explicitly on changes in occupational performance and participation. Further, these approaches are not usually used in isolation but rather as part of an overall program that also includes classic sensory integrative therapy.

Distal objectives offer greater guidance for embedding the goals of intervention in occupational participation and performance. They keep us grounded in the underlying philosophy and tenets of occupational therapy. Goals and objectives related to occupational performance issues, identified by caregivers and the child, are critical to best practice. In Chapter 8 (Assessment of Sensory Integration Functions Using the Sensory Integration and Praxis Tests), Mulligan indicated that Lilly would best be served by therapy that combined ASI with "some specific skills training for developing her pencil skills and ability to ride her bike" because these specific skills were identified as important. Establishing occupational performance and participation goals grounds us in our profession but also means we may need to engage with other practice frameworks to meet the goals of the children we treat.

Lane (2012) suggested that we embrace the concept of *universal design*, creating opportunities for all children to participate, across all environments, all the time. We can use SI theory and practice to address children's specific sensory integrative needs, but we also need to address their ability to engage with and in the multiple environments in which they live, play, and learn. Doing so embeds our sensory integrative approach in occupation and occupational therapy. It is essential that we always keep this in mind.

Toward the beginning of this chapter, we acknowledged the concerns of Rodger and colleagues (2012) with the feasibility of a sensory integrative approach. Sensory integrative therapy takes time; it may seem similar to the "slow boat" to learning specific skills (e.g., bike riding). However, if the underlying assumptions are true that therapy improves the ability of the CNS to process sensation, resulting in better body scheme, motor planning, and modulation of sensation, then, in the long run, SI may be more expedient than an approach that teaches only skills. In not addressing the underlying problem, such an approach requires that a child or adult learn every complex skill necessary for effective participation in everyday life—one at a time. That may indeed take more than 5 to 8 months. And, when children or adults tire of the arduous and time-consuming process of learning each new skill, it seems very likely that they will simply give up and reduce their participation in everyday life.

HERE'S THE POINT

- SI intervention must be situated within the realm of occupational therapy.
- Goals we establish for the child must include those related to occupational participation and performance. This may require that we use other practice frameworks in addition to SI.

Summary and Conclusions

Although recent studies offer insight into SI treatment effectiveness (e.g., Pfeiffer et al., 2011; Schaaf et al., 2014), the jury remains out. The question of effectiveness is complicated, mirroring the complexity of the intervention and theory. Ayres focused on difficulties processing and integrating sensation in the CNS. However, thus far scientists both within and outside occupational therapy have been unable to fully understand the neurological underpinnings of the disorder or to determine CNS change from intervention. Nonetheless, knowledge of the neural correlates of behaviors associated with sensory integrative dysfunction, on which Ayres based her theory, has not changed substantially, even with a deeper understanding of neuroscience.

Sensory integrative therapy is both art and science. The two are inextricably intertwined. Although science has always been thought to give the theory credibility, art gives it meaning. Perhaps some of the difficulty finding unequivocal evidence of the effectiveness of sensory integrative therapy can be attributed to researchers' separating science from art. In developing the ASIFM, theorists have made explicit the equal contributions of art and science in intervention. Current researchers who, similar to Ayres, remain faithful to all the principles of ASI have begun to demonstrate effectiveness in randomized controlled trials.

Finally, SI is only one tool in the occupational therapy toolbox. To improve everyday participation, many children require interventions based in multiple practice frameworks. Many also require the services of multiple professionals. Of course, it goes without saying that best practice is driven by goals and those goals must be situated in everyday participation.

Where Can I Find More?

Ayres, A. J. (1972). The art of therapy. In A. J. Ayres, *Sensory integration and learning disorders* (pp. 256–266). Los Angeles, CA: Western Psychological Services.

In her original book on SI, Ayres clearly articulates that therapy is both art and science. This chapter describes the art that is needed to support organization of the brain.

References

American Academy of Pediatrics, Section on Complementary and Integrative Medicine and Council on Children with Disabilities. (2012). Sensory integration therapies for children with developmental and behavioral disorders. *Pediatrics*, *129*, 1186-1190.doi:10.1542/peds.2012-0876

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Buckle, F., Franzsen, D., & Bester, J. (2011). The effect of the wearing of weighted vests on the sensory behaviour of learners diagnosed with attention deficit hyperactivity disorder within a school context. *South African Journal of Occupational Therapy*, *41*(3), 36–42.

Bundy, A., Bulkeley, K., Chapparo, C., Collier, L., Hacker, C., Jereb, D., . . . Williamson, T. (2013). Response from Bundy et al. to sensory interventions for children: Where does our profession stand? Letter to the Editor. *Australian Occupational Therapy Journal*, *60*, 221–222.

Chang, Y.-S., Owen, J. P., Desai, S. S., Hill, S. S., Arnett, A. B., Harris, J., . . . Mukherjee, P. (2014). Autism and sensory processing disorders: Shared white matter disruption in sensory pathways but divergent connectivity in social-emotional pathways. *PLOS ONE*, *9*(7), e103038. doi:10.1371/journal.pone.0103038

Cohn, E. S., & Cermak, S. A. (1998). Including the family perspective in sensory integration outcomes research. *American Journal of Occupational Therapy*, *52*, 540–546.

Cox, A. L., Gast, D. L., Luscre, D., & Ayres, K. M. (2009). The effects of weighted vest on appropriate in-seat behaviors of elementary-age students with autism and severe to profound intellectual disabilities. *Focus on Autism and Other Developmental Disabilities*, *24*, 17–26.

Dunkerley, E., Tickle-Degnen, L., & Coster, W. J. (1997). Therapist-child interaction in the middle minutes of sensory integration treatment. *American Journal of Occupational Therapy*, *51*(10), 799–805.

Fertel-Daly, D., Bedell, G., & Hinojosa, J. (2001). Effects of a weighted vest on attention to task and self-stimulatory behaviors in preschoolers with pervasive developmental disorders. *American Journal of Occupational Therapy*, *55*, 620–640.

Haley, S. M. (1994). Our measures reflect our practice and beliefs: A perspective on clinical measurement in pediatric physical therapy. *Pediatric Physical Therapy*, *6*, 142–143.

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. E. (2010a). Effects of weighted vests on classroom behavior for children with autism and cognitive impairments. *Research in Autism Spectrum Disorders*, *5*, 495–505.

Hodgetts, S., Magill-Evans, J., & Misiaszek, J. E. (2010b). Weighted vests, stereotyped behaviors and arousal in children with autism. *Journal of Autism and Developmental Disorders*, *41*, 805–814.

Iwanaga, R., Honda, S., Nakane, H., Tanaka, K., Toeda, H., & Tanaka, G. (2014). Pilot study: Efficacy of sensory integration therapy for Japanese children with high-functioning autism spectrum disorder. *Occupational Therapy International*, *21*(1), 4–11.

Kane, A., Luiselli, J. K., Dearborn, S., & Young, N. (2004). Wearing a weighted vest as intervention for children with autism/pervasive developmental disorder: Behavioral assessment of stereotype and attention to task. *Scientific Review of Mental Health Practice*, *3*, 19–24.

Kielhofner, G. (2009). *Conceptual foundations of occupational therapy practice*. Philadelphia, PA: F. A. Davis.

Kirusek, T. J., & Sherman, R. E. (1968). Goal Attainment Scaling: A general method for evaluating comprehensive community mental health programs. *Community Mental Health Journal*, *4*, 443–453.

Lane, S. J. (2012). Occupation and participation: The heart of pediatric occupational therapy: Kids want to do things. In S. J. Lane & A. C. Bundy (Eds.), *Kids can be kids* (pp. 3–9). Philadelphia, PA: F. A. Davis.

Lane, S. J., Reynolds, S., & Thacker, L. (2010). Sensory over-responsivity and ADHD: Differentiating using electrodermal responses, cortisol, and anxiety. *Frontiers in Integrative Neuroscience*, *4*(8), 1–14. doi:10.3389/fnint.2010.00008

Lane, S. J., & Schaaf, R. C. (2010). Examining the neuroscience evidence for sensory driven neuroplasticity: Implications for sensory-based occupational therapy for children and adolescents. *American Journal of Occupational Therapy*, *64*(3), 375–390. doi:10.5014/ajot.2010.09069

Lee, H.-S., & Song, C.-S. (2015). Effects of therapeutic climbing activities wearing a weighted vest on a child with attention deficit hyperactivity disorder: A case study. *Journal of Physical Therapy Science*, *27*, 3337–3339.

Leew, S. V., Stein, N. G., & Gibbard, W. B. (2010). Weighted vests' effect on social attention for toddlers with autism spectrum disorders. *Canadian Journal of Occupational Therapy*, *77*, 113–124.

Lin, H. Y., Lee, P., Chang, W. D., & Hong, F. Y. (2014). Effects of weighted vests on attention, impulse control, and on-task behavior in children with attention deficit hyperactivity disorder. *American Journal of Occupational Therapy*, *68*, 149–158. doi:10.5014/ajot.2014.009365

Mangeot, S. D., Miller, L. J., McIntosh, D. N., McGrath-Clarke, J., Simon, J., Hagerman, R. J., & Goldson, E. (2001). Sensory modulation dysfunction in children with attention-deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology*, *43*, 399–406.

May-Benson, T. A., & Koomar, J. A. (2010). Systematic review of the research evidence examining the effectiveness of interventions using a sensory integrative approach for children. *American Journal of Occupational Therapy*, *64*, 403–414.

McIntosh, D. N., Miller, L. J., Shyu, V., & Dunn, W. (1999). Overview of the Short Sensory Profile (SSP). In W. Dunn (Ed.), *The Sensory Profile: Examiner's manual* (pp. 59–73). San Antonio, TX: The Psychological Corporation.

Miller, L. J., & Kinnealey, M. (1993). Researching the effectiveness of sensory integration. *Sensory Integration Quarterly Newsletter*, *21*, 1–7.

Miller, L. J., McIntosh, D. N., Shyu, V., & Hagerman, R. J. (1999). Sensory-modulation disruption, electrodermal responses, and functional behaviors. *Developmental Medicine and Child Neurology*, *41*, 608–615.

Miller, L. J., Nielsen, D. M., & Schoen, S. A. (2012). Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology. *Research in Developmental Disabilities*, *33*(3), 804–818. doi:10.1016/j.ridd.2011.12.005

Mosey, A. C. (1981). *Occupational therapy: Configuration of a profession*. New York, NY: Raven.

Mullen, B., Champagne, T., Krishnamurty, S., Dickson, D., & Gao, R. X. (2008). Exploring the safety and therapeutic effects of deep pressure stimulation using a weighted blanket. *Occupational Therapy in Mental Health*, *24*(1), 65–89. doi:10.1300/J004v24n01

Murdock, L. C., Dantzler, J. A., Walker, A. N., & Wood, L. B. (2013). The effect of a platform swing on the independent work behaviors of children with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *29*, 50–61. doi:10.1177/1088357613509838

Ottenbacher, K. (1982). Sensory integration therapy: Affect or effect? *American Journal of Occupational Therapy*, *36*, 571–578.

Owen, J. P., Marco, E. J., Desai, S., Fourie, E., Harris, J., Hill, S. S., . . . Mukherjee, P. (2013). Abnormal white matter microstructure in children with sensory processing disorders. *NeuroImage Clinical*, *2*, 844–853. doi:10.1016/j.nicl.2013.06.009

Parham, L. D., Cohn, E. S., Spitzer, S., Koomar, J., Miller, L., Burke, J. P., . . . Summers, C. A. (2007). Fidelity in sensory integration intervention research. *American Journal of Occupational Therapy*, *61*, 216–227.

Parham, L. D., Roley, S. S., May-Benson, T., Koomar, J., Brett-Green, B., Burke, J. P., . . . Schaaf, R. C. (2011). Development of a Fidelity Measure for research on Ayres Sensory Integration. *American Journal of Occupational Therapy*, *65*, 133–142. doi:10.5014/ajot.2011.000745

Peloquin, S. M. (1989). Sustaining the art of practice in occupational therapy. *American Journal of Occupational Therapy*, *43*, 219–226.

Peloquin, S. M. (1998). The therapeutic relationship. In M. E. Neistadt & E. B. Crepeau (Eds.), *Willard & Spackman's occupational therapy* (9th ed., pp. 105–119). Philadelphia, PA: Lippincott, Williams & Wilkins.

Peloquin, S. M. (2005). Embracing our ethos, reclaiming our heart. *American Journal of Occupational Therapy*, *59*, 611–625.

Pfeiffer, B. A., Koenig, K., Kinnealey, M., Sheppard, M., & Henderson, L. (2011). Effectiveness of sensory integration interventions in children with autism spectrum disorders: A pilot study. *American Journal of Occupational Therapy*, *65*(1), 76–85. doi:10.5014/ajot.2011.09205

Polatajko, H. J., Law, M., Miller, J., Schaffer, R., & Macnab, J. (1991). The effect of a sensory integration program on academic achievement, motor performance, and self-esteem in children identified as learning disabled: Results of a clinical trial. *Occupational Therapy Journal of Research*, *11*, 155–175.

Reichow, B., Barton, E. E., Sewell, J. N., Good, L., & Wolery, M. (2010). Effects of weighted vests on the engagement of children with developmental delays and autism. *Focus on Autism and Other Developmental Disabilities*, *25*, 3–11.

Rodger, S., Ashburner, J., & Hinder, E. (2012). Sensory interventions for children: Where does our profession stand? *Australian Occupational Therapy Journal*, *59*, 337–338.

Rodger, S., Ashburner, J., & Hinder, E. (2013). Reply from Rodger et al. to response from Bundy et al. to sensory interventions for children: Where does our profession stand? *Australian Occupational Therapy Journal*, *60*, 337–338.

Schaaf, R. C. (2015). Creating evidence for practice using data-driven decision making. *American Journal of Occupational Therapy*, *69*, 6902360010p1–6902360010p6. https://doi.org/10.5014/ajot.2015.010561

Schaaf, R. C., Benevides, T., Blanche, E. I., Brett-Green, B. A., Burke, J. P., Cohn, E. S., . . . Schoen, S. A. (2010). Parasympathetic functions in children with sensory processing disorder. *Frontiers in Integrative Neuroscience*, *4*(March), 4. doi:10.3389/fnint.2010.00004

Schaaf, R. C., Benevides, T., Mailloux, Z., Faller, P., Hunt, J., Van Hooydonk, E., . . . Kelly, D. (2014). An intervention for sensory difficulties in children with autism: A randomized trial. *Journal of Autism and Developmental Disorders*, *44*(7), 1493–1506. doi:10.1007/s10803-013-1983-8

Schaaf, R. C., & Mailloux, Z. (2015). *A clinician's guide for implementing Ayres Sensory Integration®: Promoting participation in children with autism*. Rockville, MD: American Occupational Therapy Association.

Schaaf, R. C., Miller, L. J., Sewell, D., & O'Keefe, S. (2003). Children with disturbances in sensory processing: A pilot study examining the role of the parasympathetic nervous system. *American Journal of Occupational Therapy*, *57*, 442–449.

Schoen, S., Lane, S. J., Mailloux, Z., May-Benson, T. A., Parham, L. D., Roley, S. S., & Schaaf, R. C. (2019). A systematic review of Ayres Sensory Integration intervention for children with Autism. *Autism Research*, *12*, 6–19. doi:10.1002/aur.2046

Schoen, S. A., Miller, L. J., Brett-Green, B. A., & Nielsen, D. M. (2009). Physiological and behavioral differences in sensory processing: A comparison of children with autism spectrum disorder and sensory modulation disorder. *Frontiers in Integrative Neuroscience*, *3* (November), 1–11. doi:10.3389/neuro.07029.2009

Tickle-Degnen, L., & Coster, W. (1995). Therapeutic interaction and the management of challenge during the beginning minutes of sensory integration treatment. *Occupational Therapy Journal of Research*, *15*, 122–141.

Tsuchida, R., Sato, T., Yamada, T., & Matsushita, N. (1989). *Japanese version of the Miller Assessment for Preschoolers*. Tokyo, Japan: Harcourt Brace Jovanovich.

Vandenberg, N. L. (2001). The use of a weighted vest to increase on-task behavior in children with attention difficulties. *American Journal of Occupational Therapy*, *55*, 621–628.

Vargas, S., & Camilli, G. (1999). A meta-analysis of research on sensory integration treatment. *American Journal of Occupational Therapy*, *53*, 189–198.

APPENDIX

The STAR Process: An Overview

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Truth, like infinity, is to be forever approached, but never reached.

—Ayres, 1972, p. 4

The STAR Process evolved out of four decades of work analyzing intervention for individuals with Sensory Processing Disorder (SPD) using qualitative and quantitative methods. The STAR Process is rooted in the principles of sensory integration (Ayres, 1972; see also Chapter 1, Sensory Integration: A. Jean Ayres' Theory Revisited) and concepts of social-emotional interaction, particularly those drawn from DIR/Floortime™, particularly principles of relationships and engagement (Greenspan & Wieder, 1998).

Theoretical Foundations of the STAR Process

The most important theoretical aspect of the STAR Frame of Reference is that it intentionally addresses three domains of human development: regulation, relationships, and sensation (Miller, Schoen, & Spielmann, 2018).

We call the application of the STAR Frame of Reference the STAR Process. It is a process, not a set of activities or exercises. Ayres and others (e.g., Vertes, 2013) described the art of therapy as the process of following a child's "inner drive" while simultaneously challenging the child (Ayres & Robbins, 2005; Roley, Mailloux, Miller-Kuhaneck, & Glennon, 2007). In following the child's lead, we are able to maintain a focus on meaningful and functional activity and tap into the child's inner drive to learn, persevere, and succeed. The STAR Frame of Reference can be applied to adolescents and adults with some adaptations to the methodology outlined in the text that follows.

Individualize the STAR Process to the Child's and Family's Needs, "Joining" the Child to Further Relationships and Engagement

The STAR Process is individualized to each child's and family's needs in order to facilitate a therapeutic alliance. In any given session, the therapist begins by joining the child at the child's current level of functioning rather than immediately seeking to move the child to the next level. By joining with the child in play, the therapist can access the child's volition while also focusing on therapeutic tasks. By ascribing intent to play, execution of the idea and social engagement is cultivated. This dynamic process facilitates progression up the developmental ladder. For example, a child enters the therapy room and heads for the big cardboard blocks. Instead of teaching him or her to stack, the therapist watches the child carefully and tries to join what he or she is doing. If the child makes a train with the blocks, ask if another "train car" can be added. If the child builds a tower, join to make the tower taller. By joining the child, his or her world can be entered and the child and therapist join in a relationship.

The STAR Process requires the therapist (and, through coaching, the parent) to become fully immersed in the process of the activity. Csíkszentmihályi (1997) called this state "flow." When

Editor's Note: We invited Lucy Miller and her colleagues to illustrate how sensory integration theory and occupational therapy can be woven into a comprehensive intervention approach. Here Lucy Miller and colleagues describe the STAR Process, the intervention offered at the STAR Institute in Denver, Colorado.

an adult (i.e., therapist or parent) is in flow in the context of therapeutic play, that adult is totally in the moment and focused, whereas the normal "adult" distractions are forgotten. The adult becomes involved in the play as a full partner and playmate. The therapist is mindful of pre-identified parent priorities, but focuses first and foremost on immersing him- or herself in the play process rather than trying to accomplish training on discrete skills. Achieving flow is not easy and both therapists and parents should practice cultivating flow and being present. The time spent with a child should be one of authentic enjoyment. Through time it becomes easier and the energy expenditure is shared by both play partners.

Flow is the key to joy (Csíkszentmihályi, 1997). Helping parents to engage in flow in therapy is a simple concept, similar to that which Ayres discussed in her chapter "The Art of Therapy" (1972). Interactions between adult and child generate intense sensation, whereas attuned, relationship-rich processes facilitate improved regulation and sensory processing. Ultimately, such therapy leads to joie de vivre (joy in life). Joie de vivre is defined as long-term mental health and a sense of self and agency. We hypothesize that it promotes confidence and competence, leading to sensory integration and generalization of capacities. It is the harmony between intention and action and the ultimate long-term aim of therapy. The focus on creating *joy in life,* not mastering tasks of ever-increasing complexity, is one of the hardest aspects to learn about the STAR Process.

The success of the STAR Process depends heavily on the emotions (affect) conveyed by the therapist and the parent. Affect is seen in the facial, vocal, and gestural behaviors that signal underlying emotions. Affect should be sincere and attuned to the child. At times, adults may need to increase the intensity of affect, expressing enthusiasm, excitement, interest, and zeal, when playing with a child in order to facilitate the child's reading the emotions.

Seven Principles of the STAR Process

PROCESS is an acronym making the STAR Process principles readily accessible.

1. **P Play** is the platform for all therapeutic interactions.
2. **R Relationships** between the child and parent form the foundation of the STAR Process.
3. **O Organization** creates regulation and emotional stability for the child and parents' play.
4. **C Collaboration** and problem-solving with parents is key.
5. **E Enjoyment** is actively pursued.
6. **S Sensory integration** principles form the basis for action.
7. **S Success** in therapy and in life is foundational.

Each of these seven principles is highlighted in the text that follows.

1. P = Play Is the Platform for All Therapeutic Interactions

Therapy may be hard work, but it must feel similar to play. The child believes he or she is choosing the games and equipment; the therapist—and, once coached, the parents—guide the therapeutic process through continuous environmental adaptations and playful obstruction at the developmental level that facilitates the "just right" success.

In the STAR Process, play is "SMART Play" (Sensory-Motor, Attuned, Relationship-Rich Time) (Miller, Fuller, & Roetenberg, 2014). SMART Play requires that parents spend 1:1 time with their child, doing what the child chooses in a distraction-free, phone-free environment. Play and fun are needed for success, and success is motivating to continue growth. In our experience, the child who is motivated makes fast progress, whereas the child who is afraid (of negative reinforcement, for example) will make only slow progress. The STAR Process often requires parents to learn to play, letting go of their concerns and worries. One mom said recently, "Playing with my child brings me back to a place where I used to be: carefree and exuberant. It is not just that play helps my child, play helps me too!"

2. R = Relationships Between the Child and Parent Form the Foundation of the STAR Process

Many families come to the STAR center with "broken" relationships. When a child has sensory issues, the child's social relationships often are compromised by factors related to the sensory disorder, which almost always has an emotional or behavioral correlate. We carefully prioritize the parent-child bond and are aware at all times that the child-therapist relationship is secondary to the parent-child relationship. At least one parent joins each therapy session and is coached to become an active participant. By creating opportunities for success between a parent and child within the context of play, we provide opportunities for the family to rewrite entrenched scripts. An activity analysis of 50 minutes of planned activities versus 50 minutes of "following the child's lead and joining the child at his or her current level" reveals how deep the layers of learning are when a therapist or parent becomes engaged in a process-based intervention (Greenspan & Wieder, 2005). A key principle of the STAR Process is transferring the joy of mastery (e.g., when a child makes a giant leap forward) from therapist-child to parent-child. We call that **giving away magic moments.** This may sound simple, but it requires great skill and is among the most meaningful parts of the STAR Process. Parents deserve the magic.

3. O = Organization Creates Regulation and Emotional Stability for the Child and Parents' Play

Parents typically provide regulation for infants, who, as they mature, become responsible for their own self-regulation. Often the first goal in therapy is to help a child attain a regulated state and to expand his or her range of emotions. Methods for regulating arousal must be individualized and require an understanding of what dysregulates or regulates a particular child. A child who is running around aimlessly is unlikely to make much progress. A child who is sitting alone, lethargic, is unlikely to initiate or even notice overtures from those who might support him or her. When children have behavioral issues, at any given moment, we first check to make sure they are regulated. Connect before correcting; young brains are wired to rely on the regulatory capacity of their caregivers' frontal lobes through the teenage years (Siegel, 2011). The therapist models regulation strategies (e.g., breathes deeply and slows the pace). The therapist also provides a few, simple rules, utilizing specific sensory input and creating predictability with routines and actions. Frustration, often experienced in a therapy session, provides an opportunity to work on emotion regulation. We acknowledge and validate a child's feelings, often labeling or mirroring emotions back to the child. This provides the foundation for emotion awareness. Children do not have the capacity to reason when they are upset, but talking or drawing about the experience afterwards is helpful. Working through frustration in a session is not wasted time but an opportunity to support improved emotion regulation.

4. C = Collaboration and Problem-Solving with Parents Is Key

Collaboration is most effective in the context of issues that naturally occur. An essential skill for parents to learn is how to collaborate with their child to achieve desired outcomes. The goal here is that the child and parent work together rather than the parent dictating what the child should do. Collaboration also describes the relationship between the parent and the therapist. The STAR Process uses A SECRET (Bialer & Miller, 2011) to guide parents in collaborative problem-solving to address their child's most difficult challenges. (See also Chapter 14, Distilling Sensory Integration Theory for Use: Making Sense of the Complexity.)

5. E = Enjoyment Is Actively Pursued

Children with SPD almost always have atypical emotional reactivity, manifested as aggression or anxiety (Ben-Sasson, Carter, & Briggs-Gowan, 2009). These feelings interfere with experiencing joy. Once the child feels joyful, he or she is likely to increase mastery and success.

6. S = Sensory Integration Principles Form the Basis for Action

Sensory integration theory is an integral part of the STAR Process. Ayres' (1972) influence is seen as primary aspects of the reasoning process: providing enriched sensory opportunities; regulating arousal; normalizing responses to sensory experiences; increasing body awareness and discrimination abilities; providing a foundation for posture, praxis, and higher level action using the just right challenge; tapping the child's inner drive; and active participation.

7. S = Success in Therapy and in Life Is Foundational

The "just-right" success is sought in therapy as much as the "just-right" challenge. Success is the basis of self-esteem, self-confidence, and joie de vivre.

The Six Procedural Requirements

The comprehensive STAR Process adheres specifically to the six procedural requirements described in the text that follows.[1]

1. Intensive short-term treatment
2. Parent collaboration, education, and coaching
3. Options for treatment by clinicians from multiple disciplines
4. Goal development: Reasonable expectations through joint goals
5. Rich mentorship of therapists from supervision and team collaboration opportunities
6. Focus on a sensory lifestyle

1. Intensive Short-Term Treatment

Sessions with a child and parent occur 3 to 5 days per week for a total of approximately 30 sessions, depending on the child's needs. To facilitate therapeutic alliances, each child has a primary therapist (i.e., the child does not float between therapists). All families have at least two online sessions after they leave the face-to-face intervention process; parents determine the content for those sessions. We can use online conferences to connect with teachers or other therapists, talk to parents or the child, or for any other useful purpose the family chooses.

2. Parent Collaboration, Education, and Coaching

The STAR Process is a parent-empowerment and collaborative approach addressing a child's challenges and parent-child interactions. Using the STAR Process requires parents to have an interest in gaining insight into their own processes and relationships rather than primarily in changing their child. The STAR Process strives to connect parents to other "sensory parents" and, for those interested, provides adult treatment focused on empowerment, education, and self-training.

3. Options for Treatment by Clinicians from Multiple Disciplines

The STAR Process reflects the perspectives of multiple professional disciplines, including occupational therapy and speech or language pathology, as well as mental health therapies such as psychoanalytic therapies, family therapy, DIR/Floortime approach, marriage and family therapy, clinical social work, clinical psychology, listening therapy, feeding therapy, and others. The result is an amalgamated intervention model representing best practice from many fields. The method has evolved, and will continue to evolve, as we learn more through a collaborative, multidisciplinary team.

4. Goal Development: Reasonable Expectations Through Joint Goals

The Goal Attainment Scale is completed both pre- and post-treatment so parents and therapists have aligned and reasonable expectations for change. Parents' goals are prioritized as we learn about their main concerns for change. We also compare pre- and post-treatment scores on standardized performance measures and standardized parent report measures.

5. Rich Mentorship of Therapists from Supervision and Team Collaboration Opportunities

Each therapist is mentored weekly by a supervisor with a mental health background and each participates in co-mentoring with another therapist. An approach such as the STAR Process requires substantial time from therapists to ensure that all are on the same page and working together to attain the same goals and using the same principles.

6. Focus on a Sensory Lifestyle

A sensory lifestyle involves environmental accommodations, altered expectations of

[1]The STAR Process follows the Process points and the procedures described herein. However, we realize that therapists may not be able to follow all procedures because of the culture of their practice environment. The Process may be followed with great success even if the procedural guidelines (such as intensive treatment) cannot be followed exactly.

caregivers and educators, and continuous availability of the organizing sensory experiences that are specific to that child's needs. It is a 24-hour lifestyle change. Where possible, parents are encouraged to apply principles of A SECRET (Bialer & Miller, 2011) all the time, every day, and not just in the sensory gym. Natural environments support the seven key principles of the STAR Process. We find that settings such as our sensory playground and sensory garden support carryover into community settings.

Summary and Conclusion

In this appendix, we provide a summary of the STAR Process: a sensory, emotion, and parent education approach. The following table defines the major points in the STAR Process. It can be used as a simple fidelity measure for the STAR Process when being researched.

Evidence-based research is critical to developing improved quality of care for children and their families. Our experience with the STAR Process suggests that this approach, in addition to being effective, is fun and rewarding for everyone. We recently completed a study of the effectiveness of the STAR Process with 179 children. Results demonstrated change in *adaptive behavior* on the Adaptive Behavior Assessment Scale, *emotional functioning* on the Behavior Assessment Scale for Children, *sensory-related behaviors* on the Sensory Processing Three Dimensions Parent Inventory, and *motor changes* on the Miller Function and Participation Scale or the Bruininks-Oseretsky Test of Motor Proficiency. For detailed information see Schoen, Miller, and Flanagan (2018).

Process Points: Fidelity Measure for STAR Process

SENSORY SUBTYPES AS A FOUNDATION FOR INTERVENTION USING THE STAR PROCESS	OBSERVED	NOT OBSERVED
Evaluate and define the child's sensory subtype(s) before starting intervention		
Principles of the STAR Process: Fidelity to the Process Checklist		
Think process, not activities		
Individualize your approach to the child and parents' level and needs		
Join the child in accomplishing his or her chosen task		
Work in "flow" fully immersed in process as a full partner		
Get to "joy" by being fully immersed in the play		
Play from a place of authentic enjoyment that is not fabricated		
Adjust your affect as needed by sensory subtype		
Focus to arousal regulation through coregulation and other techniques		
Educate on SMART play and offer "homework" around play time		
Connect with parent(s) as well as the child; honor parents' gifts and strengths		
Maintain personal boundaries		
Support parent-child relationship (not therapist-child relationship)		
Give away magic moments to the parent		
Include principles of sensory integration intervention		
Discuss only a few simple rules		

Process Points: Fidelity Measure for STAR Process—cont'd

SENSORY SUBTYPES AS A FOUNDATION FOR INTERVENTION USING THE STAR PROCESS	OBSERVED	NOT OBSERVED
Evaluate emotion stability and recognition of emotion states; acknowledge and validate child and parents' emotions; share your emotions		
Establish trusting relationship with the parent and child		
Use repetition to make actions automatic; add novelty to work on flexibility		
Show parents how to empower their child with "you can" statements, choices, positive self-talk, taking turns, and so on		
Work with parents on A SECRET, focusing on a sensory lifestyle (not a sensory diet) Reinforce parents' ability to problem-solve for their child.		
Work from success, scaffolding as necessary		
Build self-confidence and self-esteem		
Grade the process of play to the "just right" challenge and "just right" success		
Procedural Requirements		
Intensive short-term treatment		
Parent collaboration, education, and coaching sessions scheduled where parents are empowered to feel successful and SMART Play is discussed		
Options for treatment by multiple disciplines		
Access to a range of sensory and motor equipment		
Environment provides physical safety		
Goal Attainment Scale developed supporting parents' priorities		
Mentorship provided to treating therapists		
Individual supervision provided to each therapist and team discussion of each case		
Treatment options such as dyads, triads, quartets, or in groups or camps		
Offer opportunities to participate in outcomes research		
Have fun!!		

STAR Fidelity Measure based on work by Miller, Schoen, Porter, Chu, and Parkins. 2014

References

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles, CA: Western Psychological Services.

Ayres, A. J., & Robbins, J. (2005). *Sensory integration and the child: Understanding hidden sensory challenges* (25th Anniversary). Los Angeles, CA: Western Psychological Services.

Ben-Sasson, A., Carter, A. S., & Briggs-Gowan, M. J. (2009). Sensory over-responsivity in elementary school: Prevalence and social-emotional correlates. *Journal of Abnormal Child Psychology*, *37*(5), 705–716.

Bialer, D. S., & Miller, L. J. (2011). *No longer A SECRET: Unique common sense strategies for children with sensory or motor challenges*. Arlington, TX: Sensory World.

Csíkszentmihályi, M. (1997). *Finding flow: The psychology of engagement with everyday life*. London, UK: Basic Books.

Greenspan, S. I., & Wieder, S. (1998). *The child with special needs: Encouraging intellectual and emotional growth*. New York, NY: Perseus Books.

Greenspan, S. I., & Wieder, S. (2005). *The hardest part of Floortime: Following the child's lead and challenging the child at the same time*. Web Based Radio Show Transcript, 1–19.

Miller, L. J., Fuller, D. A., & Roetenberg, J. (2014). *Sensational kids revised edition: Hope and help for children with sensory processing disorder (SPD)*. New York, NY: Penguin.

Miller, L. J., Schoen, S. A., & Spielmann, V. A. (2018). A frame of reference for sensory processing difficulties: Sensory Therapies and Research (STAR). In P. Kramer, J. Hinojosa, & T. Howe (Eds.), *Frames of reference for pediatric occupational therapy* (4th ed., pp. 159–202). Philadelphia, PA: Wolters Kluwer.

Roley, S. S., Mailloux, Z., Miller-Kuhaneck, H., & Glennon, T. (2007). Understanding Ayres' sensory integration. *AOTA Continuing Education*, *12*(17), 1–8. Retrieved from http://digitalcommons.sacredheart.edu/ot_fac/15/

Schoen, S., Miller, L., & Flanagan, J. (2018). A retrospective pre-post treatment study of occupational therapy intervention for children with sensory challenges. *Open Journal of Occupational Therapy*, *6*(1). doi:10.15453/2168-6408.1367

Siegel, D. J. (2011). *The neurobiology of we* [Audiobook]. Louisville, CO: Sounds True.

Vertes, J. (2013). Multisensory deficits. In R. C. O'Reilly, T. Morlet, & S. L. Cushing (Eds.), *Manual of pediatric balance disorders* (pp. 301–308). San Diego, CA: Plural Publishing Inc.

GLOSSARY

accessory optic tract the smallest visual pathway

action potential electrical signal generated and carried to the cell body of the first order neuron when changes to the energy of the initial signal are of sufficient strength

action systems theory ecological theory that focuses on the functional specificity and meaning of actions and emphasizes the need to study actions within natural contexts

activities of daily living (ADLs) activities that involve taking care of and moving one's own body; examples include dressing, bathing, eating, and functional mobility

adaptive mechanisms occur when body position is perturbed, necessitating a response to maintain the position

adaptive response a skilled or goal-directed response to an environmental challenge; the desired outcome of a sensory integration therapeutic activity

affective aggression coined by Bear and colleagues to describe the emotional response of an animal in the presence of a threatening stimulus

afferent a nerve carrying a message toward the central nervous system

amacrine interneurons interneurons located in the retina, that exert an inhibitory influence; they interact with retinal ganglion cells and bipolar cells

ampulla enlarged end of the semicircular canals

amygdala structure that has a highly important role in processing emotions, especially fear, anger, sadness, and disgust

ankle strategies reactions in response to weight shifting when balance is challenged

anterolateral system or **spinothalamic pathway** one of the two main subdivisions that comprise the somatosensory system; conveys crude touch, pain, and temperature.

anticipatory mechanisms activation of postural muscles in preparation for skilled action

apraxia disorder that interferes with the ability to perform learned actions and impedes the ability to use gesture for communication in the absence of paralysis, sensory loss, or disturbance of muscle tone

arousal a state of the nervous system, describing how alert one feels

attention deficit-hyperactivity disorder (ADHD) the most common neurobiological disorder that manifests in childhood, characterized by persistent and maladaptive symptoms of inattention, hyperactivity, and impulsivity; includes three clinical presentations: combined, predominantly inattentive, and predominantly hyperactive-impulsive

autonomic nervous system (ANS) division of the peripheral nervous system that regulates body functions such as the heart and respiratory rate; divided into sympathetic and parasympathetic branches

aversiveness (aversive response) to movement sensory over-responsivity characterized by autonomic nervous system responses to movement that most individuals would not find noxious; linked with poor vestibular processing

Ayres Sensory Integration® (ASI) an intervention process adheres to the essential principles of sensory integration (SI) theory as defined by Ayres; used to distinguish authentic SI intervention from other sensory-based approaches

behavior regulation the ability of an individual to exhibit self-control, and the ability to manage behavior in ways that are appropriate to the situation

belt pathway an auditory pathway that transmits information relative to the timing and intensity of input, which contributes to bilateral interaction of sound input

bilateral integration the ability to use both sides of the body together in a skillful manner; includes crossing of the midline

blob regions cylindrical shapes within the visual cortex comprising groups of neurons sensitive to color

body scheme the neural representation of the body used to guide motor activity; based heavily on proprioceptive and tactile sensory input

chemonocioceptors receptors that are activated by the release of chemical substances when tissue is damaged

cingulate gyrus a cortical structure with numerous connections within the limbic system; it receives input from the hippocampus and sends input to the dorsal medial nucleus of the thalamus

clinical observations relatively standard set of structured observations that complement standardized assessment of sensory integrative functioning

coaching a means for assisting parents and teachers to solve problems commonly encountered in their parenting or teaching roles with children with a disability

coaching action real-life events in the context of which coaching partners implement new strategies for parenting or teaching a child

coaching feedback feedback provided in a respectful and reflective way to expand coaching partners' understanding of a situation and to develop or refine strategies

coaching observation therapist-coach observes the actions of a coaching partner for the purpose of providing feedback, or a coaching partner observes a coach in order to develop new ideas, strategies, or skills

coaching reflection analysis, in-the-moment and later, of the implementation and outcomes associated with new strategies to determine if, and in what ways, the strategies require modification

cochlea receptors for the auditory system located in the inner ear

Cognitive Orientation to daily Occupational Performance (CO-OP) model an intervention approach often used with children with developmental coordination disorder that applies cognitive problem-solving, dynamic performance analysis, and enabling principles to guide children to discover strategies that enable them to reach functional goals

comorbid when two or more disorders occur simultaneously within the same person

components of the STEP-SI intervention model sensation, task, and environment

contexts environmental features that influence occupational performance: cultural, physical, social, personal, spiritual, temporal, or virtual

contrast or edge detector name for the visual system because of cells in the primary visual cortex that are sensitive to the outline of an object but not to its interior

co-occupations occupations that have shared meaning, engaged in, or influenced by at least two individuals

co-regulate to regulate one's state and emotions in order to help a child regulate his or her state and emotions

coregulation dynamic interaction between social partners (usually adult and child) in which the regulatory arousal system is adaptively modified

core pathway one of two primary pathways of the auditory system to the central nervous system; it maintains tonotopic organization of input and transmits sound frequency with speed and great accuracy

corollary the process by which internal correlates of motor signals are sent to muscles after an action is planned; an important source of proprioception

cortisol hormone released by the adrenal cortex in response to stress; byproduct of the hypothalamic pituitary adrenal axis system

cribriform plate thin bony structure in the nasal cavity that forms a passageway for the olfactory nerve

detection the ability to discriminate a positive stimulus from a null stimulus; an aspect of sensory discrimination

developmental coordination disorder (DCD) neurodevelopmental disorder in which motor performance is significantly lower than expected given the person's age and previous experiences; DCD may be diagnosed when motor symptoms cannot be explained by intellectual disability or other neurological condition

diadokokinesia the ability to perform rapid, alternating movements

diffusion tensor imaging (DTI) type of magnetic resonance imaging that measures microscopic movement of water in the brain; used to evaluate the integrity of white matter connectivity in the brain

discrimination see *sensory discrimination*

distal objectives therapeutic goals targeting skills, abilities, and behaviors directly related to participation challenges

domain-specific strategies (DSSs) within the Cognitive Orientation to daily Occupational Performance (CO-OP) approach, task- and context-specific strategies to support functional goal acquisition; may include verbal guidance, body positioning, attention to doing, task modification, verbal rote scripts, and so on

dopamine neurotransmitter present in the brain which is associated with motor control and reward-motivated behavior

duration quality of sensation that refers to the length of time a sensation is present

Dynamic Interactional Model of Cognition intervention model that views cognitive functions as ongoing products of the dynamic interactions among people, activities, and environments

dynamic performance analysis (DPA) within the Cognitive Orientation to daily Occupational Performance (CO-OP) approach, a process by which the therapist breaks down a task into component parts so that the parts presenting difficulties for an individual can be identified and targeted for intervention

dynamical systems theory challenges traditional views that human development proceeds in an orderly and consistent pattern across individuals; describes motor behavior as fluid, highly variable, and dependent on interaction with the surrounding world through the exploration of new contexts

dyspraxia developmental condition in which the ability to plan unfamiliar motor tasks is impaired; motor planning deficits are developmental rather than acquired

effectiveness a determination of whether an intervention is beneficial under "real world" conditions, such as routine clinical practice

efficacy a determination of whether an intervention produces the expected result under ideal circumstances, such as in a research laboratory

electrodermal response (EDR) changes in electrical conductivity of the skin regulated by the sympathetic nervous system; thought to be an indication of psychological or physiological arousal

electroencephalogram (EEG) technique used to measure event-related potentials, or small voltages in the brain that result from localized recruitment of synchronous neuronal firing

enabling principles within the Cognitive Orientation to daily Occupational Performance (CO-OP) approach, fundamental concepts that promote learning by capturing attention and engaging a child to work toward independence

environment (as used in the STEP-SI intervention) organization, complexity, perceived comfort and safety, and possibilities for engagement, exploration, expansion, and self-challenge

environmental enrichment paradigm used in basic science studies in which animals are housed in conditions that provide enhanced sensory, motor, and social opportunities

epigenetics the study of changes in behavior or appearance caused by mechanisms other than changes in the underlying DNA sequence; the study of how environmental influences may change genetic expression

evoked response potential (ERP) electrical potential recorded from the central nervous system following presentation of a stimulus

executive functions cognitive skills such as attention, judgment, concentration, and inhibition largely controlled by the prefrontal cortex

feedback-dependent tasks tasks requiring ongoing modification because of sensory feedback

feedforward-control the ability to initiate an action before feedback is available

fidelity the extent to which an intervention was carried out as intended or outlined in the intervention manual

food neophobia fear of new foods

fovea depression at the center of the retina with a high concentration of cones; responsible for sharp central vision

framing in the context of play-based therapeutic intervention such as sensory integration treatment, framing involves giving and reading verbal and non-verbal cues that assist players in understanding how to treat one another in play, and that increase the likelihood that all players will have fun

frequency quality of sensation that refers to how often the sensation occurs during a specific unit of time

functional magnetic resonance imaging (fMRI) functional brain imaging procedure that measures brain activity by detecting changes associated with blood flow

generalizability the degree to which research findings or scores can be extended to a different population (e.g., across cultures) or to performance in a different environment (e.g., lab vs. natural setting)

generalization the ability to transfer a skill learned in a therapeutic context into a real-world setting; also refers to the ability to integrate a skill learned in isolation into a more functional multi-step task

Goal Attainment Scaling (GAS) standardized method of scoring the extent to which a child's individual goals are achieved throughout the course of intervention

Goal-Plan-Do-Check within the Cognitive Orientation to daily Occupational Performance approach (CO-OP), a problem-solving strategy whereby specific strategies are identified for solving performance problems related to a desired task or activity; the individual learns how, when, and where to use the strategies to support performance, generalization, and skill transfer

golgi tendon organs (GTO) receptors located at the origins and insertions of skeletal muscle that detect changes in muscle tension; a source of proprioceptive input

graphemes the smallest distinguishing unit in written language (e.g., letters)

gravitational insecurity (GI) sensory over-responsivity that manifests as a fear of movement, being out of an upright position, or having one's feet off the ground; linked to poor otolithic vestibular processing

guided discovery within the Cognitive Orientation to daily Occupational Performance (CO-OP) approach, facilitated active learning in which the therapist promotes self-learning to enable children to discover strategies for solving performance difficulties through questioning, coaching, and provision of opportunities for reflection

habituation a process of adapting to sensory input; becoming less responsive to repeated sensation

heart rate variability physiological measure of variation in the time interval between heartbeats; regulated by both sympathetic and parasympathetic branches of the autonomic nervous system

hippocampus a limbic structure that has been hypothesized to play a role in sensory modulation; seems to be linked with spatial mapping and memory

homogeneity the similarity or uniformity of characteristics within or between groups

horizontal interneurons interneurons of the retina that exert an inhibitory influence

hypogeusia reduced sensitivity to taste stimuli

hyposmia reduced ability to smell

hypothalamic pituitary adrenal (HPA) axis complex set of interactions among the central nervous system and the endocrine system that influences the body's reaction to stress

hypothalamus a small region of the brain that integrates information from the cortex with input from the spinal cord and brainstem, acting as a control center for autonomic nervous system mechanisms

ideation a component of motor planning that involves generating ideas for action and knowing which actions are appropriate for which objects

inner drive the motivation to direct one's own actions meaningfully and with satisfaction

instrumental activities of daily living (IADLs) activities that support an independent lifestyle and involve interacting with the environment (e.g., driving, medication management, meal preparation, shopping)

intensity measurable property of sensation that may be influenced by stimulus strength, rhythmicity, duration, frequency, or speed

interactions (as used in the STEP-SI intervention approach) interpersonal interaction style, including responses to supportive, nurturing styles vs. more challenging, authoritative styles; locus of control; and demands or expectations for engagement

internal consistency how well items on an assessment measure the intended construct; a form of reliability

internal control the most important element of play whereby children feel empowered to create and engage in play situations of their own making; they are free to suspend some constraints of reality by transforming objects, assuming different roles, and bending some of the usual rules

interoception sensing the physiological condition of the body; awareness of internal sensations (e.g., hunger, thirst, heartbeat)

intrinsic motivation an element of play whereby activities are done for their own sake—for the pleasure of engaging in them

Joint planning of coaching process by which therapist-coach and coaching partner clarify the problem, set a goal, and identify actions to address the goal

just-right challenge a task that requires a child to work at the edge of his or her capabilities and facilitates an adaptive response

levels of evidence rating system used to rank the strength of research outcomes used to determine the effectiveness of an intervention and make recommendations

limbic motor cortex midbrain structures that interface between subcortical and cortical structures; involved in emotion, homeostasis, learning, and memory

long-term memory the ability to hold and recall a small amount of information in the mind for a long period of time

magnetoencephalography (MEG) a functional neuroimaging technique that uses sensitive magnetometers to map brain activity

manualized intervention intervention that has been standardized through the creation of manuals and protocols; interventionists are trained to implement the intervention according to standard procedures

meaningful clusters groups of scores or behaviors that reflect one underlying construct; for instance, we look for a group of behaviors, such as resistance to have hair cut, hair brushed, teeth brushed, and wearing shirts with tags, as a meaningful cluster of behaviors suggesting tactile defensiveness; one behavior on its own (e.g., being bothered by tags in a T-shirt) is not enough to suggest tactile defensiveness

mechanonociceptors receptors for the anterolateral system that respond when tissue is damaged

mesencephalon region of the brain that connects the hindbrain and forebrain, comprised of the tectum, cerebral peduncle, tegementum, and substantia nigra; also called the midbrain

meta-analysis a research method used to increase the power of research findings by statistically combining the results of several independent studies

mismatch negativity (MMN) common method to measure auditory discrimination abilities by comparing brain waves elicited by a repeated standard sound with those elicited by a rarer deviant sound; it is the most common method used for measuring auditory discrimination abilities

mother space space approximately 8″ to 10″ from an adult where a child is free to take simple risks while still feeling a sense of safety and security

motor control the regulation and refinement of movement that has already been acquired

motor learning the acquisition of motor skills

motor planning the ability to plan motor tasks

motor unit the alpha motor neuron and all the muscle fibers to which it connects

multi-modal approach an intervention approach that includes many different types of treatment methods

muscle spindles stretch receptors located alongside muscle fibers that identify changes in muscle length; the primary source of proprioceptive input

neuroendocrine system mechanism by which the brain, primarily the hypothalamus, maintains homeostasis through hormonal regulation; associated with control of metabolism, eating and drinking behavior, energy utilization, and blood pressure

neuroplasticity changes in brain organization or connectivity that occur throughout the life span in response to experiences

neuroprotective care a standard care practice for NICU providers that emphasizes stress and pain reduction, position and handling techniques, partnering with families, and the regulation of sleep/states of arousal

nystagmus a compensatory ocular movement occurring in response to movement

occupational profile history of engagement in needed and desired activities

occupations activities done by the individual that are perceived as meaningful and give purpose and structure to their lives

ocular tracking the act of moving the eyes in a smooth and accurate manner across a line or from one object to another

odorants airborne chemical stimuli involved with the detection of smell

olfactory bulb forebrain structure responsible for receiving and processing information about odorants

olfactory epithelium layer of receptor cells lining the nose that detect odorants in the environment

orienting response a subcortical action in response to novelty in the environment

parallel processing sensory processing that involves multiple sensory systems simultaneously carrying and interpreting the same sensation

participation taking part or involving one's self in a given task or activity

per-rotary nystagmus nystagmus that occurs during head rotation

phonemes the smallest possible sounds in words

photoreceptors vision receptors (i.e., rods and cones) located in the neural retina at the back of the eye that transduce light energy into electrical energy to be transmitted to the central nervous system

play a transaction that is relatively intrinsically motivated, relatively internally controlled, free of many of the unnecessary constraints of objective reality, and that is demarcated by clear cues, separating play from the rest of everyday life

population coding a form of neural coding in which sensory stimuli are represented by the joint activity of groups of neurons

positron emission tomography (PET) radiological functional imaging technique used to gather information about the functionality and structural integrity of the organ

post-rotary nystagmus nystagmus that takes place after rotation

postural-ocular control functions necessary to maintain proximal stability, postural orientation, and a stable visual field

postural orientation an appropriate relationship among body segments, the task, and the environment

praxis the ability to plan unfamiliar motor tasks

praxis on verbal command pattern found in factor analyses and cluster analyses that showed the ability to follow single and multi-step unfamiliar verbal instructions; when a pattern of difficulty emerges in this area in the absence of other difficulties in sensory integration and praxis, it is felt to be a speech and language problem and not necessarily a sensory integration deficit

predictability (as used in the STEP-SI intervention approach) novelty, expectation, structure, routine, transitions, and congruency; level of control by child or practitioner and control of events and routines

projected action sequences motor tasks that involve a sequence of precisely timed and placed movements; dependent on adequate feedforward processing

proprioception perception of joint and body movements as well as position of the body, or body segments, in space

protective factors aspects of the person or environment (i.e., conditions, skills, resources) that reduce risk or assist individuals in dealing with stress or challenging events

proximal objectives therapeutic goals targeting factors underlying participation difficulties (e.g., poor praxis, difficulty processing and integrating sensation)

proximal stability generalized muscle tone and alterations to tone that allow postural reactions in response to gravity and maintenance of body alignment

proxy-report a report completed by someone else (i.e., a parent) about a child's behavior or performance

psychosis a severe mental disorder in which thought and emotions are impaired such that contact is lost with reality; symptoms include delusions, hallucinations, disorganized speech, or grossly disorganized or catatonic behavior

randomized controlled trial (RCT) a type of scientific experiment where subjects are allocated randomly to experimental and control conditions

reactive attachment disorder (RAD) an internalizing trauma and stress-related mental disorder characterized by an inability to be comforted by adequate caregivers because of insufficient care during infancy or early childhood

receptor or receptive field area around a receptor from which input can be transduced into an electrical signal

recognition the ability to tell two positive (non-null) stimuli apart; an aspect of sensory discrimination

reflection-in-action the reflective conversation of a therapist whereby the therapist "speaks" and the situation "talks back" so that the therapist appreciates her or his thoughts about what is happening, reframes the situation, and takes any necessary action

reframing in coaching a process by which a therapist-coach enables a coaching partner to understand a child's behavior in a different way or to view behaviors from a new perspective

reliability the extent to which a test consistently measures what it is intended to measure

respiratory sinus arrhythmia physiological phenomenon reflecting heart rate variability in synchrony with respiration

rhythmicity quality of sensation that refers to the regularity of repetition of the sensation

Scarpa's ganglion vestibular nerve ganglion, where the cell bodies for the vestibular nerve are located

Self-Monitoring (as used in the STEP-SI intervention approach) moving children from dependence on external cues and supports to a self-directed and internally organized ability to modify their own behavior and manage challenges

self-regulation the ability to attain, maintain, and change one's arousal appropriately for a task or situation

Sensation (as used in the STEP-SI intervention approach) comprises both *sensory modalities:* tactile, vestibular, proprioception, audition, vision, taste, olfaction, oral input, and respiration and *qualities of sensation:* duration, intensity, frequency, complexity, and rhythmicity

sensitization aversive response to a specific stimulus is generalized to other, previously non-aversive, stimuli

sensorimotor self-regulation the most basic, foundational level and the focus of the Alert Program®; occurs at relatively "low levels" of the nervous system and supports the emergence of higher cognitive functioning, including regulation on emotional and social levels

Sensory Challenge Protocol (SCP) laboratory paradigm in which sensory stimuli are systematically presented to research subjects during collection of physiological data

sensory defensiveness disorganized responses to sensory input across more than one sensory system

sensory diet therapeutic use of sensation in the context of daily activities; based on the concept that controlled sensory input can affect functional abilities

sensory discrimination the ability to tell stimuli apart by processing salient information such as loudness, position, texture, and shape; the ability to interpret the spatial and temporal qualities of sensation

sensory discrimination disorder deficiency in the ability to discriminate sensations in any sensory system, or across sensory systems, in a way that impairs occupational performance

sensory homunculus a physical representation of the body based on the distribution of the somatosensory cortex; body parts with more touch receptors are depicted as larger than those with few

sensory integrative dysfunction umbrella term for disorders of sensory integration that include differences in sensory responsivity, discrimination, perception, and use of sensation for movement

sensory modulation dysfunction disorders in sensory responsivity that are thought to reflect an underlying modulatory dysfunction of the central nervous system; encompasses problems of sensory over-responsivity and sensory under-responsivity

sensory over-responsivity a type of sensory modulation disorder that results in responses to sensation that are exaggerated, prolonged, or more intense than required by the situational demands; often manifested in "fight or flight" behaviors

sensory perception interpretation of sensory stimuli and the use of that interpretation as a basis for interacting with the world; a foundation for sensory discrimination, postural ocular skills, visual motor skills, body scheme development, and praxis

sensory processing disorder an alternative term to sensory integrative dysfunction coined by Miller and colleagues in their quest to have the disorder entered into the *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*

sensory responsiveness pattern found in factor analyses characterized by over, under, and fluctuating responses to the intensity and duration of one or more sensations; atypical responses are often accompanied by discomfort with usual activities and difficulty with self-regulation of emotions, activity level, alertness, and attention

sensory rooms rooms outfitted with multiple sensory modalities that are primarily geared toward stress prevention and comfort, decreasing distress or agitation, and for de-escalation of difficult behaviors

sensory under-responsivity a type of sensory modulation disorder that results in responses to sensation that are diminished or less intense than required by the situational demands

septal region region of the brain that serves as a relay between the hippocampus and the hypothalamus; it receives input from the olfactory and limbic systems and projects to the hypothalamus

serial processing sensory processing in which single sensory systems process sensation in sequence, in a hierarchical manner

short-term memory the ability to hold and recall a small amount of information in the mind for a short period of time (a few seconds)

skin-to-skin care technique in the care of preterm infants in which the infant is held against the skin of a parent

slow movements movements that are controlled, smooth, fluid, slow, and symmetrical

Snoezelen™ room a type of sensory room that provides a variety of sensory experiences, generally used with adults with moderate to severe cognitive impairments such as dementia or psychosis; these rooms aim to promote relaxation and social interaction

somatodyspraxia motor planning problems that arise from deficits in discrimination of tactile, proprioceptive, and, to a lesser extent, vestibular sensations that result in poor body awareness

somatopraxis/somatodyspraxia pattern found in factor analyses and cluster analyses that showed the relationship between tactile discrimination and imitation, related to the ability to plan, execute, and generalize action plans based on good body awareness

somatosensation/somatosensory collection terms for tactile and proprioceptive sensations

somatosensory evoked potential electrical potential recorded following presentation of a somatosensory stimulus

spatial discrimination in auditory processing, the ability to locate the source of sounds and relative position of objects in the environment; a prerequisite skill for efficient communication and interaction in complex environments

speed quality of sensation that refers to the rate of stimulus occurrence or movement

stapes a small bone in he middle ear that conducts sound vibrations to the inner ear

state anxiety a state of heightened emotions that develop in response to a specific fear or danger of a particular situation

stereognosis commonly assessed discriminative skill associated with the somatosensory system that requires integration of tactile and proprioceptive inputs in three-dimensional object discrimination; also involves visual memory

stimulant medications medications such as methylphenidate that work by increasing levels of dopamine and norepinephrine in the brain; used to manage behaviors associated with attention deficit-hyperactivity disorder such as hyperactivity and inattention

strength quality of sensation that refers to the force with which the sensation is administered

striatum subcortical structures (the caudate, putamen, and nucleus accumbens) that make up part of the basal ganglia and contribute to decision-making, behavior, and voluntary movement

surround inhibition or inhibitory surround neurons at the center of the receptor field activate inhibitory interneurons, which connect with sensory neurons farther from the center of the receptive field and inhibit transmission at the periphery of the receptive field

synactive theory a dynamic systems theory specific to NICU care that conceptualizes infants' self-regulatory capacities as the interplay between autonomic, behavioral state, motor, attentional and interactive subsystems, and aims to facilitate a match between the infants' capacities and the demands of care

systematic review form of literature review that examines and critically analyzes findings across multiple studies to provide a high level of evidence

systems or ecological theories contextual theories of motor behavior

tactile defensiveness type of sensory modulation disorder that results in responses to tactile sensation that are exaggerated, prolonged, or more intense than required by the situational demands; often manifested in "fight or flight" behaviors

tactile discrimination the ability to tell tactile stimuli apart by processing salient information such as texture, and shape

tactile sensation awareness or perception of the location, or change in position, of an external stimulus applied to the skin

task knowledge reflects an understanding of what a task involves with respect to what a child needs to do and what (if any) equipment or environmental supports are required to complete the task

tectum midbrain structure comprised of the inferior and superior colliculi, associated with the auditory and visual systems, respectively

temperament individual differences in behavioral tendencies that appear early in life and tend to remain stable throughout the course of time

temporal coding a form of neural coding in which sensory stimuli are represented by the temporal firing patterns of neurons

teratogenic insult occurs when a harmful substance (teratogen—usually drug or other chemical) affects the developing brain in utero

therapeutic use of self therapist's ability to nuance sensation embedded within an interaction with a child to create an environment that promotes positive change and that guides the child's reaction so that he or she mirrors the therapist's regulated state, resulting in positive emotions

trait anxiety a general level of anxiety that is related to personality, and that results in an individual becoming easily stressed and anxious

transactional developmental theory a systems theory describing early development with three main components—the infant, the caregiver, and the environment—that emphasizes how each of the three components interact and affect one another and how they contribute to developmental outcomes

trauma experiences or events that are threatening or harmful, emotionally or physically, and have an adverse influence on a person's physical, emotional, social, and spiritual functioning and well-being

trauma-informed care (TIC) an interdisciplinary intervention approach used with children with disorders of trauma and attachment; emphasizes use of techniques that support recovery from trauma and the development of secure relationships with caregivers

unstructured observation in the context of clinical observations, observations used to capture the qualitative aspects of motor performance and more elusive functions; or, observations conducted to capture behaviors from a child who is interacting freely in a natural environment

vagal tone activity of the vagus nerve influencing heart rate; used as an index for the functional state of the parasympathetic nervous system

validity the extent to which a test measures the construct(s) it intends to measure

velocity storage a mechanism associated with the vestibular nuclei in which velocity information generated by movement is collected and stored and then released slowly, generating nystagmus

vestibular bilateral integration and sequencing (VBIS) pattern found in factor analyses and cluster analyses that showed the relationship between vestibular functions, postural and ocular control, laterality, and bilateral motor control; when there is difficulty with this pattern, it predicts difficulty with posture, balance, sitting still, and learning such as reading, writing, and math

vestibular bilateral integration and sequencing (VBIS) deficits motor planning problems thought to be the result of poor processing of vestibular and proprioceptive sensations, manifesting as poor postural-ocular control and difficulty using two sides of the body in a coordinated manner

visual attention involves focusing the visual system on an object or target and filtering out the visual information that is not salient to the task at hand; present but immature at birth

visual cognition set of skills that includes visual attention, memory, and discrimination

visual construction a perceptual activity that integrates visual discrimination abilities with motor responses

visual memory the ability to interpret visual information based on previous experience

visual perception the ability to recognize, discriminate, and interpret visual stimuli

visual perceptual processing the ability to use information contained in visible light to interpret and make sense of the world

visuopraxis/visuodyspraxia pattern found in factor analyses and cluster analyses that showed the relation between vision and visual construction, signifying the ability to use vision to guide the use of environmental affordances as tools and to understand the spatial awareness of the body relative to people and environment

visuo-somatodyspraxia somatodyspraxia combined with visual-spatial problems

womb spaces small, protected spaces that are separate from a child's primary environment and evoke feelings of security and safety

word-in-noise the ability to distinguish a word spoken within a noisy background; auditory discrimination

Zones of Regulation a curriculum aimed at teaching children and adults about behavioral regulation, understanding emotions, and gaining skills in consciously regulating their actions and problem-solving abilities

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