A Tale of Two Cases: Lessons for Education From the Study of Two Boys Living With Half Their Brains

Mary Helen Immordino-Yang[1]

ABSTRACT—In recent years, educators have been looking increasingly to neuroscience to inform their understanding of how children's brain and cognitive development are shaped by their learning experiences. However, while this new interdisciplinary approach presents an unprecedented opportunity to explore and debate the educational implications of neuropsychological research, a good model for this dialogue is lacking. This is in part because relatively little is known about the relationships between cognitive, emotional, and neurological development, in part because of a dearth of research methods designed to rigorously connect issues of learning and development to neuropsychological strengths and weaknesses, and in part because neuropsychological studies are rarely presented in a format that is conducive to meaningful cross-disciplinary dialogue with educators. To begin to address these issues, in this article, I present the complementary cases of Nico and Brooke, two high-functioning adolescents, who have suffered the removal of an entire brain hemisphere (Nico his right and Brooke his left) to control severe epilepsy. Through presenting a neuropsychological study of these rare boys' emotion and affective prosody (vocal intonation) through the developmental lens of an educator, I reinterpret the neuropsychological findings for what they reveal about how the boys leveraged their emotional and cognitive strengths to learn important skills for which they were each missing half of the normally recruited neural hardware. While Nico's and Brooke's results seem on the surface to contradict expectations based on neuropsychological findings with adults, they combine to reveal a compensatory logic that begins to elucidate the active role of the learner as well as the organizing role of emotion in brain development, providing a jumping-off point for discussion between educators and neuroscientists and a model for connecting neuropsychological strengths and weaknesses to learning.

In recent years, educators have been looking increasingly to neuroscience to inform their understanding of how children's brain and cognitive development are shaped by their learning experiences (Diamond & Hopson, 1998; National Research Council, 1999). Brain development is coming to be viewed as an active, dynamic process, one in which a learner's approach to problem solving may actually serve to organize his or her brain over time and, conversely, one in which a learner's particular neuropsychological strengths may in turn shape his or her problem-solving approach. Because of the bidirectional nature of the relationship between learning and brain development, the fields of neuroscience and education are coming increasingly into a research partnership to investigate the ways that this developmental interaction plays out. However, while this new interdisciplinary approach presents an unprecedented opportunity to explore and debate the educational implications of neuropsychological research, relatively little is currently known about the basic principles governing the organization of children's brain and cognitive development in relation to experience.

One of the reasons for this lack of knowledge is that, although educators intuitively recognize the importance of emotional and social considerations in understanding children's development, there is currently very little research that effectively integrates social and emotional considerations into the study of brain development. The neurological

[1]Brain and Creativity Institute/Rossier School of Education, University of Southern California

Address correspondence to Mary Helen Immordino-Yang, 3641 Watt Way Suite B17, Los Angeles, CA 90089-2520; e-mail: mhimmordino-yang@post.harvard.edu.

research on emotions is unequivocal; the biological and cognitive processes that constitute emotion involve complex and dynamic feedback loops, at times under and at times out of our conscious control, between the physiology of the body and brain (Damasio, 1999). Imagine the automatic goose pimples you feel at hearing of another's misfortune or the rush of memories you harbor of the moments just after the horrifying events of 9/11. Contrary to a long philosophical tradition in which rational thought ruled (Damasio, 1994; Haidt, 2001), we now know that emotions involve the largely automatic and often nonconscious induction of behavioral and cognitive packages, which percolate into and out of our conscious minds, influencing our decision making, our thinking, our memory, and learning (Immordino-Yang & Damasio, 2007). Add to this mix the concept of social emotions, that is, that we are influenced not only by our own but also by others' emotions, behaviors, and mental states, and an amazingly complex landscape emerges. Very little is known about how all this plays out in educational contexts, in which people of different cultures, backgrounds, and neurological profiles are interacting, feeling, and learning. And so, while the few existing neurological studies of the development of emotion in children (e.g., Baird, Gruber, & Fein, 1999; Murray et al., 2006) have garnered much interest from the educational community and the general public, the application of these findings to educational contexts is difficult and often misguided because, unlike in psychological development (e.g., Case, 1996, 1997; Fischer & Immordino-Yang, 2002), there is no good framework with which to understand the role of emotion in shaping the development of neuropsychological skills.

One window through which to investigate the developmental principles governing the brain–experience relationship and the organizing role of emotion is through case studies of atypical but highly functioning children. While their cases must be interpreted with caution, such children afford us a unique angle from which to explore these questions, as their active compensation for neuropsychological deficits can reveal subtle organizational principles that are better hidden in the more typical developmental trajectories of normal children. When a child is missing the brain areas that would normally be required to perform a particular task, and yet manages to successfully compensate, we are given a unique opportunity to learn about the emotional and motivational aspects of their recovery, as well as about cognitive compensation for basic neuropsychological skills. How are they learning what they should be unable to learn? Careful studies of such children's development can provide a good forum in which to debate the functional relationships between cognition and emotion in brain development and from which to begin to establish a framework for understanding the hidden developmental processes acting in more typically developing children.

TRIANGULATING BETWEEN SOCIOEMOTIONAL, NEUROPSYCHOLOGICAL, AND DEVELOPMENTAL PERSPECTIVES: WHAT NICO AND BROOKE CAN TEACH US ABOUT THE NATURE OF LEARNING

Given these considerations, the purpose of this article is to illustrate the value of understanding the full range of variation in development by presenting comparative neuropsychological case analyses of the development of two exceptional adolescent boys, Nico and Brooke,[1] each of whom suffered severe localized brain seizures during childhood that resulted in the surgical removal of an entire hemisphere of his brain. In this comparative case method, each hemispherectomized boy was compared to normal matched peers on a series of educationally and socially relevant prosodic and emotional tasks, and the results of these comparisons were juxtaposed. This design was chosen for three main reasons: First, prosodic and emotional skills are thought to involve particular roles for each brain hemisphere, so studying these skills enabled rigorous assessments of how the boys had learned what they should not have been able to learn by traditional accounts. Second, this design revealed the possible organizing role of emotion in the boys' learning. Third, it allowed me to connect findings about these boys' functioning to issues of learning and development with broader educational relevance.

Amazingly, despite the poor cognitive prognosis generally associated with removal of a brain hemisphere, both Nico and Brooke have compensated to previously unexpected degrees. Nico lost his right hemisphere at age 3; yet, he is now a charming and sociable 14-year-old, attending a mainstream school in Spain. (His family is Argentine and moved to Spain after the testing described here.) His favorite activities are fencing, drawing cartoon characters, and singing in his school choir, and he rushes smiling to kiss my cheek whenever we meet. Brooke lost his left hemisphere at age 11, but despite predictions that he would never talk again, graduated from high school and began attending part-time college a few months after testing. He lives with his grandmother and continues to enjoy his job bagging groceries at a local supermarket. Both of these boys are hardworking young men, and while some effects of their neurological trauma endure, they are self-assured and proud of their accomplishments.

Such boys as these are extremely rare, and we will never know if their successful outcomes may have been possible in part because of individual differences in their presurgery neurological profiles. In addition, their families and teachers may have played a major role in their recoveries, through allowing these boys the freedom to actively engage in their own learning, without restricting them to preconceived notions about how they would function or recover after surgery. Their schools' help in overcoming the low-level mechanistic and motor skills that could have impaired their progress, such as by providing a computer and typing instruction to Nico to

circumvent his fine-motor difficulty with handwriting, may have also contributed. In short, we still have many questions about these boys, including why they have fared so much better than others with similar neurological histories and how their recoveries might have differed because of their different ages at the time of surgery.

Nonetheless, irrespective of the factors above, Nico's and Brooke's successful compensation for their extensive brain damage is extremely interesting from a developmental point of view and begs us to explore the broader principles governing the ways that they have adapted. How have these boys compensated and what can we learn from them about how the developing brain makes sense of emotional and cognitive experience, given an extreme profile of strengths and weaknesses? In this article, I investigate these questions through analyzing these boys' emotional development and their use of emotional intonation (affective prosody) in speech, because these complex, socially relevant skills are thought to be carried out bilaterally in the brain, with each hemisphere having a particular role. Because each boy is missing half of the neural tissue normally recruited for these skills, understanding the boys' development in these areas could lead to important insights, with implications for education as well as for our understanding of prosodic and emotional processing in the brain.

Specifically, although we often assume that everyone perceives the same educational problems in the same ways, for example, a math problem is a math problem for everyone, Nico's and Brooke's cases suggest that we can in fact approach even relatively low-level, apparently automatic processing in very different ways, given extreme developmental circumstances. In particular, it appears that, perhaps in part due to highly supportive educational environments, both boys have compensated for lost abilities by transforming processing problems they should not be able to deal with given their neurological profiles into qualitatively different problems that better suit their remaining strengths.

Furthermore, it appears that, for both boys, their emotional profile plays a major role in shaping their brain development. In other words, both boys have distinctive emotional biases in approaching the social world, the signatures of which can be found in their solutions to cognitive problems, such as their approach to understanding and producing certain aspects of speech. Were this to hold true for other learners as well, it would imply that educators should think seriously about the problems they put to their students and the various neuropsychological ways that these problems could actually be interpreted and processed. What we intend as a simple math exercise, for example, could in essence be a verbal problem to one child, a spatial problem to another, and even an affective or social problem to a third, who may be thinking of the emotional implications of, say, the solution to a mathematics word problem. As we could imagine, each of these children would be approaching the math problem from a very different angle that would have repercussions for their performance. While neuropsychology would have little to say about the most appropriate methods of support and teaching for each child, a neuropsychological approach could inform educators' understanding of the possible strategies each child could be using (Immordino-Yang, 2001a).

Working From a Neuropsychological Perspective

Before reading more about these cases, there are several background premises that would be useful to make explicit because they are borrowed from standard neuropsychological approaches and may be unfamiliar to educators. First, in studying such cases, we are comparing atypical to typical function to tell us about the component processes and developmental principles involved in normal functioning (Caramazza, 1992). That is, we seek to understand atypical function not simply for its own sake but for what it can reveal about the ways all children learn and grow. When functions break down or fail to develop as expected, we are afforded a unique opportunity to learn about the ways in which the brain and mind organize themselves over time, in this case, via the ways that children functionally compensate for their neurological deficits after hemispherectomy.

Second, to understand the principles that govern brain organization processes in Nico and Brooke requires a developmental analysis of their evolving skill profiles in a particular domain—in short, *how* they are doing what they are doing. It is this *how* that should be of most interest to educators because it is presumably the aspect of neuropsychological development that is most influenced by developmental experience, as well as the most likely area in which to discover conclusions generalizable to other children. Too often in the past, brain-based education has stymied itself with detailed accounts of neurological details that, quite simply, are not relevant to the majority of educational concerns (Bruer, 1997). Here, I take a more productive approach, in which educational and neuroscientific perspectives are brought together over specific cases to think about the interplay between learning experiences and biological predispositions and mechanisms, including emotional ones.

Third and related, moving from the long, neuroscientific localizationist tradition in which cognitive functions were mapped onto specific locations in the brain (Harrington, 1991), in studying these cases, our general interest is in the development of the relationship between brain and behavior, and the role of experience in organizing the brain and mind (Immordino-Yang, 2001b; Immordino-Yang & Fischer, 2007). In other words, we are interested less in *where* functions are in the brain and more in *why* they are there (Bates, Thal, & Marchman, 1991; Deacon, 2000). This is a cutting-edge area that shapes the design and interpretation of experimental

work in the neurosciences and is ripe for educational contributions, because educators and developmental psychologists see the behavioral manifestations of these hidden neuropsychological processes. In children, cognitive functions are more broadly distributed and less well localized to specific brain areas (Johnson, 2000). This means that they are also less efficient and more plastic, usually able to shift their organization more readily than in adults (Bates et al., 2001). Over time and with experience, these cognitive functions become increasingly modularized and localized, as the brain networks on which they depend become more efficient and less susceptible to major reorganization through cognitive experience. It is this general trend through development from broadly distributed, relatively inefficient but plastic processing to localized, efficient, but relatively fixed processing, which makes neuroscientific concerns so relevant to education, as knowledge about this trend can inform the design of effective learning environments and experiences. It also forms my primary interest in the study of Nico and Brooke, as these boys' surprisingly successful outcomes probably depend heavily on this developmental canalization process. Through careful analysis of these boys' functioning, then, I aim to discover something about the compensatory logic underlying their developmental neuropsychological reorganization and thereby to learn more about the interaction between brain development and cognitive and affective experience.

Bridging the Educational Gulf

After introducing these cases, we can see that they are especially appropriate for educational scrutiny for several reasons. First, too often neuropsychological work focuses overly on either the cognitive or the affective aspects of processing, a bias which is sometimes necessary for methodological reasons, but which makes extrapolation to real-life learning contexts and educationally relevant learning principles infinitely more speculative. My study makes a compromise on this front, sufficiently narrowing the domain of processing studied to produce rigorous results, but maintaining a sufficiently broad perspective to consider simultaneously both affective and cognitive contributions to the boys' compensatory strategies.

Second, rather than focusing in-depth on one kind of task and one level of analysis, this study moves from basic measures of neuropsychological processing through to more complex, naturalistic measures that more closely simulate skills relevant to real social contexts. In so doing, it provides entry points for both neuropsychologists and educators to debate the study's implications, not just *what* the boys are doing but *how* they are doing it. For example, because prosody is a socially relevant cognitive skill, will there be differences in the ways the boys process prosody depending on whether the prosody is embedded in a social context or divorced from social concerns? And if so, will emotional considerations explain these differences? How will the two boys' processing differ, given that they are working with opposite hemispheres?

Third and related, to build more complete profiles of the boys than are typical in neuropsychology, the same data are analyzed on several dimensions: affective and cognitive, productive and receptive, and in individual and group analyses. Fourth, in making sense of neuroscientific work, educators are most concerned with understanding the interaction between the individual and the learning environment in building knowledge structures and shaping the brain. My study lends itself well to this concern, as it affords a unique window into developmental plasticity and the processes that govern neurological reorganization in response to experience.

Thus, this article is conceived as a narrative, an attempt to tell the story of two closely related domains of processing in Nico and Brooke, in order to engage neuroscientists and educators together in a discussion of the educational implications of data from these rare individuals. I first present nontechnical accounts of my work on the boys' emotion and use of emotional intonation in language, known as affective prosody. In these sections, I describe my theoretical motivations, methods, and results with only the detail necessary to engage nonexperts in the topic and approach and to familiarize them with the findings. (Interested readers should refer to Immordino-Yang, 2005, for full empirical reports on the prosody studies.) In interpreting the results, I use the emotional findings as a lens through which to more deeply understand the results of the neuropsychological prosodic assessments. The discussion explores the educational implications of bringing together these analyses and begins to build connections between these two boys and broader conceptual issues in education. Overall, this article is meant as a first foray into a new, smarter brand of brain-based education, one in which specific neuropsychological studies are presented, debated, and used to advance educational theory.

NICO'S AND BROOKE'S AFFECTIVE PROSODY AND EMOTION: LEARNING WHAT ONE IS UNABLE TO LEARN

In language, one way emotion is expressed is through prosody, which is the intonational contour, or melody, and stress pattern of speech (Crystal, 1997; Monrad-Krohn, 1948; Ross, 2000). Through manipulating the contour of an utterance, speakers can convey various emotional states and pragmatic intents, from the rising pitch of a question, to the exaggerated emphasis of sarcasm:

Person A: "I'm going to Timbuktu next summer."
Person B: "YOU'RE going?"
Person C: "You're GOING?"

In this example, both B and C are incredulous about A's travel plans, but B thinks that someone else should go or that A in particular is not fit to go, while C had been under the impression that A had previously decided not to go. These nuances of meaning and affect are conveyed through linguistic intonation and accompanying paralinguistic cues, such as the facial expressions of B and C.

In normally developing children, emotion and prosody are likely integrated very early on, so that we do not think to examine the relationship between these two sets of skills (Bloom, 1997). However, in most adults, the syntactic and semantic aspects of language are mainly localized to the left hemisphere of the brain, while affective prosody and its associated skills are mainly handled by the right hemisphere (Kandel, Schwartz, & Jessell, 2000; Ross, 2000; Ross, Thompson, & Yenkowsky, 1997). This means that, during normal development, an integrative process between the two hemispheres must take place for appropriate affective intonation to be incorporated into the syntax and meaning of speech.

Further, while nonlinguistic emotional processing is not as clearly divided between the two hemispheres, the emotional profiles associated with left and right hemisphere damage are distinct (Lezak, 1995). Given this, extensive work over the past decades has attempted to divine the emotional profiles of the two hemispheres. This work has led to much controversy, but in general, it is accepted that the right hemisphere is more strongly implicated in emotion (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Compton, Heller, Banich, Palmieri, & Miller, 2000; Perry et al., 2001), especially facial expression of affect (Borod, Koff, Yecker, Santschi, & Schmidt, 1998; Corina, Bellugi, & Reilly, 1999) and the ability to feel and perceive negative emotions (Campbell, 1982; Jansari, Tranel, & Adolphs, 2000).

As both Nico and Brooke have fully functional language despite missing a brain hemisphere, the question then arises as to how they have compensated, both prosodically and emotionally. In these boys, neurological damage has disassociated the skills associated with each hemisphere; each is missing half of the neural hardware normally relied upon for affectively appropriate language use.

One of the clues to understanding their good outcomes may well lie in concurrently examining not simply their cognitive ability to compensate for the basic-level perceptual mechanisms necessary to use and understand affective prosody but their emotional motivation and strategy for doing so. While there is a history of work on recovery of language in hemispherectomized children (e.g., Boatman et al., 1999; Piacentini & Hynd, 1988; Smith & Sugar, 1975), there has been almost no work done on emotional or prosodic processing by these children, except to note that extensive brain injury usually results in behavioral and emotional problems (Hawley, 2003). Profiles of emotional (Trauner, Nass, & Ballantyne, 2001) and prosodic (Trauner, Ballantyne, Friedland, & Chase, 1996) deficit associated with less pervasive right- versus left-hemisphere lesions have yielded few differences between right- and left-hemisphere–damaged groups, although patients with right-hemisphere lesions may fare worse than those with left-hemisphere lesions on measures of recognition of facial affect (Voeller, Hanson, & Wendt, 1988).

These inconclusive results are related to the fact that brain processes seem to be less well organized in children than in adults. Processing in children is also more widely distributed around the brain and less focalized, and the localization of functions is more plastic (Kandel et al., 2000). Because of this, localized brain damage in children results in somewhat different patterns from damage in adults, both of deficit and of recovery (Bates et al., 2001). Compared to adults, in children, the location of damage corresponds less predictably to the resulting neuropsychological profile. And, while severely brain-damaged children usually do not catch up to their peers, they sometimes recover remarkably well, unlike adults with comparable brain damage (Reilly, Bates, & Marchman, 1998). In short, children benefit from increased plasticity, in which intact brain regions presumably compensate for damaged areas (Battro, 2000). Because there is significant variability in children's paths to recovery from brain damage, case studies can contribute important insights into these trends and the plasticity that created them.

In particular, a basic question has to do with the extent to which intact brain regions actually assume the processing characteristics of the damaged regions and the extent to which they adapt the cognitive problem to fit their characteristic mode of processing. In this study, Nico, with an intact left hemisphere, could be processing prosody in either of two ways, which would have distinct signatures in his data. He could be processing prosody much like his peers or younger children, which would suggest that his left hemisphere has, by necessity, taken on the kind of processing normally handled by the right hemisphere. Or, he could be processing prosody as if it were the kind of syntactic problem that the left hemisphere normally handles, in effect an aspect of grammar rather than a means to emotional expression, which would result in a qualitatively different data pattern than normal children show.

This distinction has implications for education. The first scenario suggests that plasticity mainly involves building new strengths to solve problems as they are put to you; the second scenario suggests that, at least in some cases, plasticity is about transforming the cognitive problem itself into a form that suits one's processing strengths. While Nico and Brooke represent exceptional cases in which to study this distinction, their exceptionality offers unique viewpoints onto a normally hidden process. All children (and, in fact, adults) assimilate and adapt to new information and problems from their environments, and while we presume that this is an active process, the more we can learn about it, the better we

can design learning environments and experiences to support it. In short, information about Nico's and Brooke's overall approach to compensating should be of interest to educators because it has potential implications for all children.

And thus, we come back around to the *how* at the interface of education and neuroscience: taking a case study approach to studying these boys affords us a privileged view into a process that presumably all children are using in adapting their brains to the developmental challenges the world poses. To what extent are Nico and Brooke compensating by adapting their existing brain tissue to behave like the missing tissue would have, and to what extent are they transforming the processing problem to suit the original strengths of the tissue they have retained? To explore these questions, we move now to the methods and results of the study, starting with affective prosody and proceeding to nonlinguistic emotion.

DOING THE SCIENCE: COMPARATIVE CASE ANALYSIS WITHIN A DEVELOPMENTAL AND SOCIAL FRAMEWORK

My study comprises a four-way design in which I compare production and reception of nonlinguistic emotion and affective prosody for Nico, Brooke, and comparison boys, to characterize the boys' functioning in these domains and investigate how functioning in emotion and prosody may covary after hemispherectomy (see Figure 1). I have included tests of both reception and production because, from a neuropsychological perspective, these may recruit different skills, strategies, or neuropsychological mechanisms, especially in two boys who are actively compensating both cognitively and neurologically for massive neurological trauma. For each hemispherectomized adolescent and each measure, a body of comparison data was collected, including cross-sectional longitudinal data from at least three 8-, 10-, and 12-year-olds, in addition to data from at least 10 age-matched comparison subjects and 3 adults. (Adult data was used only to verify the measures and was not included in the analysis.) Comparison boys were monolinguals of American English– or Argentine Spanish–speaking parents, with no diagnosed learning disabilities or neurological or hearing problems, matched to each hemispherectomized boy on linguistic dialect (either Buenos Aires Spanish or northeastern American English), approximate socioeconomic status, and approximate scholastic ability.

In all but Ekman's test of facial affect recognition, the boys' skills are characterized along a continuum of complexity that is meant as a means to describe a developmental trajectory. Here, I am extending an established microdevelopmental approach used for the study of emotion and cognition (Fischer & Bidell, 1998) into the domain of prosody. In this approach, single constructs, such as describing feelings of happiness or taking the first-order perspective of one other person, are presumed to be less developmentally advanced than an integrated description or display of a set of constructs, such as a joint description of happiness and feelings of reciprocated trust or understanding one person's perspective on a second person's feelings. For prosody, I consider discriminating a single prosodic feature such as rising tone to be less complex and less developed than combining prosodic features to effect a subtler emotional message, such as sarcasm. In employing this complexity approach, I am bringing a developmental perspective to the established clinical neuropsychological dimensions of emotional and prosodic intensity and emotional valence.

Prosody

While I am drawing on established procedures to describe the boys' emotional functioning, the lack of appropriate developmental assessments for prosodic functioning required me to design my own measures. Basing my innovations on ideas and findings from the developmental and neuropsychological literatures, the prosodic receptive tests consist of a battery of tape-recorded items to which subjects respond and justify their answers. These items range from simple discrimination of the melodic patterns in speech and systematically increase in complexity to finally test inferences about speakers' affective intent in a naturalistic story (see Table 1 for a description of the test conditions). In my battery, story conditions systematically manipulate the presence of context information, tone of voice information, and a required integration of the two sources to predict the story outcome or infer a speaker's affect.

For example, a key distinction was between two story conditions: *context* and *tone*. Examine the following illustrative test items:

> John and Joe were playing soccer in the park. John kicked the ball towards the goal ...
> ... The ball bounced off the goal post and hit John in the head.
> Joe told John it was a nice shot. (Story ending for the *context* condition)
> OR
> ... Joe said, "Nice Shot!" (Story ending for the *tone* condition)
> Why did Joe say that it was a nice shot?
> Was Joe being serious, being funny, or was he lying?
> How do you know that?
> Did John really make a nice shot?

In each case, the participant is asked to judge whether the final statement in the story had been sarcastic or sincere and to justify his answers via a series of follow-up questions. However, in the context condition, this judgment is

	Emotion	Prosody
Reception	**Ekman'sTest of Facial Affect Recognition** (Ekman& Friesen, 1975) **Research Question:** How can Nico's and Brooke's emotional receptive abilities be characterized, compared to established norms? •110 close-up photos of actors' faces depicting anger, disgust, fear, happiness, surprise, sadness, and neutral affect •Data analyzed for emotion recognition ability as well as for any signs of bias towards emotions of a negative (-) or positive (+) valence (e.g. systematically mistaking fear (-) for surprise (+), or interpreting neutral affect as negative) •Has established norms; no need for comparison subjects.	**Immordino-Yang's Test of Prosodic Discrimination and Comprehension** **Research Question:** How can Nico'sand Brooke's prosodic reception be characterized, both developmentally in terms of complexity and normatively in terms of strategy? •Designed audio-taped tests to measure basic discrimination of linguistic intonation and stress (e.g. rising vs. falling pitch), and comprehension of these features in story contexts (e.g. sarcastic vs. sincere tone of voice) •Data analyzed developmentally for ability to integrate increasingly complex cues (e.g. story context and speaker tone) and normatively for solution strategy used (e.g. perspective taking) •Comparison data collected from 10 age and language-matched boys for Nico and Brooke, from 3 adults in each language, and from three 8, 10 and 12 -year-olds in each language.
Production	**Self-In-Relationships Interview (SIR)** (Fischer &Kennedy,1997; Kennedy, 1994) **Research Question:** How can the complexity, valence and intensity of N and B's emotional production be characterized, compared to typically developing boys? •Clinical-style emotional interview in which participants describe their feelings and thoughts about themselves and important personal relationships •Data analyzed by complexity (i.e. the ability to represent and integrate several emotions in one relationship), by valence (e.g. a preference for describing mainly the negative or positive aspects of relationships), and by intensity •Typical performances well described; no need for comparison subjects	**Immordino-Yang's Analysis of Naturalistic Speech Production in the SIR** **RqesearchQuestion:** How can the intonation in N and B's speech be characterized in relation to that of typically developing boys? •Using speech analysis software, analyzed sentence-level intonation fluctuation produced during prosodic receptive story conditions •Data analyzed for amount of pitch fluctuation and for distribution of pitch ranges across utterance •Audio-recorded data from prosodic reception story conditions from 3 age-and language-matched comparison boys for Nico and for Brooke

Fig. 1. Overview of design, measures, research questions, and analyses*.
Note. All boys were tested in their native regional dialects. Comparison boys were monolinguals tested in Nico's and Brooke's home regions of Argentina and United States, respectively. Test development, data analysis, and reliability coding were done with the help of native Argentine Spanish and American English speakers throughout the study.

based upon the congruence of the content in the utterance and story. That is, incongruence indicates that the speaker was joking (or lying), while congruence indicates sincerity. On the other hand, in the tone condition, participants must judge a speaker's intent based on the intonation of their utterance alone, as the context of the story leaves ambiguous the speaker's intent.

I conducted two levels of analysis on the prosodic reception data. First, I scored the subjects' answers on each item as either correct or incorrect and calculated descriptive statistics for the comparison groups. Nico's and Brooke's scores were then compared, in standard deviations, to the mean scores of their same-language comparison groups and to the mean of their same-language age mates. I next undertook a qualitative and quantitative analysis of the justifications that each subject used in the tests involving story scenarios and produced characterizations of the strategy profiles used by Nico and Brooke. Here, I analyzed how Nico, Brooke, and comparison boys explained correct and incorrect answers, and investigated whether Nico and Brooke appeared to be developing normally, using strategies that are similar to those of their peers, whether they were delayed, using strategies similar to those of younger children, or whether they appeared to be following different developmental trajectories altogether. In particular,

Table 1
Prosodic Receptive Test Conditions, Examples, and Comments

- Discriminate the rising intonation patterns of questions from the falling patterns of statements: For example, "You have a cat." versus "You have a cat?" (This is relatively robust neuropsychologically and represents a very basic use of intonation to understand speaker's intent.)
- Discriminate melodic patterns in speech ("pitch contour matching"): Subjects listen to two phrases with the same number of syllables but different intonation, and then match an intonational pattern on "na na" to one of the original phrases. (Items were balanced for primarily rising vs. primarily falling pitch.)
- Discriminate stress patterns that have differences for meaning: Subjects differentiate by stress otherwise identical phrases (in English) or words (in Spanish), for example, "hot dog" vs. "hotdog" or "papá" (daddy) vs. "papa" (potato)
- Understand story context and use this to predict a speaker's intent to joke, deceive, or be sincere

  "John and Joe were playing soccer in the park. John kicked the ball towards the goal. The ball bounced off the goal post and hit John in the head, and he slipped and fell in a mud puddle. Joe told John it was a nice shot."

  Why did Joe say that it was a nice shot?

  Was Joe being serious or funny when he said it was a nice shot?

  How do you know that?

  Did John really make a nice shot?
- Identify sarcastic versus sincere tone of voice in the final statement of a sarcastically ambiguous story and associate these tones with a speaker's intent to either joke/disparage or be serious

  "John and Joe were playing soccer in the park. John kicked the ball towards the goal. Joe said, "Nice shot!" (Followed by similar questions to the context condition.)
- Integrate story context with tone of voice information to infer the outcome of a story or to choose an appropriately intoned ending statement (13 items)

  "On her way home from school, Nina stopped at the candy store and asked for an orange lollipop. The woman at the store gave her an orange soda. Nina said, "Excuse me, but I asked for an orange LOLLIPOP." Or, "Excuse me, but I asked for an ORANGE lollipop." (The stress and intonation in the first choice indicate that there was an error with the type, not flavor, of product. This is the correct choice, given the story context.)

Note. Each test condition contained 10 items plus a practice item, unless otherwise noted.

I was interested in Nico's and Brooke's use of tone of voice as a cue to sarcasm, as well as in the emotional and social aspects of their strategies. Dimensions on which the data were analyzed included the following:

- subjects' judgments about the speaker's intent to joke, deceive, express sincerity, or some combination;
- subjects' perspective taking, which involved inferences about story characters' feelings or mental states;
- subjects' restating, inferring, or extrapolating factual information from the story;
- subjects' use of personal experience as a reference point in making judgments about story characters;
- subjects' explicit reliance on tone of voice information in making judgments;
- subjects' use of generalizable rules to justify judgments about story characters; and
- the internal consistency as well as plausibility of subjects' answers.

(See Immordino-Yang, 2005, for a detailed description of coding and analytic procedures. Here and below, comparisons were made on the basis of distributions as this was the most sensible way to compare one boy to a group.)

In my prosodic production analyses, I investigated the boys' spontaneous speech during the prosodic receptive testing session, through acoustically analyzing the original recordings of their answers. Because the most important acoustic feature of affective prosody is the manipulation of pitch (Bolinger, 1989; Crystal, 1997; Ohala, 1984; Scherer, 1986), technically known as fundamental frequency, I measured the lowest and the highest pitches produced during each utterance for each boy, and subtracted the low from the high value to produce a pitch range for each utterance. This enabled me to broadly characterize the boys' control of pitch in their expressive language, a neuropsychological skill that is heavily tied to emotion and, in most people, heavily recruits the right but likely involves both brain hemispheres (Cancelliere & Kertesz, 1990; Kotz et al., 2003; Pell, 1998; Pell & Baum, 1997; Ross et al., 1997; Schlanger, Schlanger, & Gerstman, 1976; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994; Tompkins & Flowers, 1985; Van Lancker & Sidtis, 1992; Van Lancker-Sidtis, 2004).

Emotion

This study included two tests of emotion, one of production and one of reception. In order to describe the complexity, valence, and intensity of Nico's and Brooke's emotional production, each boy participated in a standard cognitive and emotional "Self-in-Relationships" interview (SIR).[2] This clinical-style interview provides a supportive context in which participants are asked to describe their feelings and understandings about themselves in their important personal relationships. It has been shown to be an effective way to support adolescents in constructing complex understandings of themselves and their feelings and to assess the developmental level of these constructions (Fischer & Kennedy, 1997; Kennedy, 1994). In the interview, participants generate adjectives to describe their feelings in personal relationships; assign positive, negative, or neutral valence to these adjectives; and, with the help of a diagram, explain connections between different feelings. Normal adolescent boys can be expected to produce multifaceted positive and negative descriptions in this context and, when supported, to explain how different feelings go together. Boys of Brooke's age should also be able to integrate across emotions and relationships, to build abstract understandings of the ways that they feel, think, and act in their close relationships (Fischer & Bidell, 1998). Because typical performances for adolescents of different ages have been well described, no comparison data was collected for this phase.

In analyzing these data, I looked for evidence of emotional valence, from negative (e.g., sadness, anger) to positive (e.g., happiness, security), and of emotional intensity. To do this, I reviewed the list of adjectives that each boy produced and the valences that he assigned to these descriptors. For example, Nico had often been described as having very positive affect. Especially when specifically asked, did he talk about negative feelings, such as sadness or frustration, as well?

Next, I assessed the complexity of the boys' understandings, looking for evidence of single emotions such as happiness being incorporated into richer descriptions of connections between emotions or between similar emotions within different personal relationships. For instance, in talking about the grandmother who raised him, did Brooke integrate his feelings in a complex way, to describe how his feelings of security, for example, related to his feelings of resentment at being disciplined? Alternatively, did he simply list several emotions, such as security and resentment, without forging connections? Assuming that he produced both positive and negative emotion terms, did he make equally complex connections between negative as between positive emotions?

To complement this assessment of emotional production, Nico's and Brooke's abilities to discriminate basic emotions on faces was also tested using Ekman's test of recognition of facial expression of emotion (Ekman & Friesen, 1975). This test consists of 110 close-up photos of actors' faces depicting anger, disgust, fear, happiness, surprise, and sadness, as well as photos depicting neutral affect. These photos were developed for basic and cross-cultural research on emotion and have been adapted for use in neuropsychological studies (Lezak, 1995). Nico and Brooke were asked to view each photo and to identify the emotion being produced by the person in the photo.

The boys' responses were analyzed in two ways. First, I calculated the percentage of correct answers and tabulated the patterns of errors that the boys made. Then, I conducted a secondary analysis of the boys' responses, looking for evidence of systematicity or bias in the boys' correct and incorrect answers. For instance, was there evidence that Nico tended to confuse negative emotions, such as fear and disgust, but accurately differentiate positive emotions, such as happiness and surprise? Alternatively, might he or Brooke have shown a tendency to misclassify negative emotions as positive, for example, confuse disgust with surprise? The results of this secondary analysis were then integrated with and understood in terms of the results of the SIR interview.

BUILDING CONNECTIONS BETWEEN THE BRAIN AND LEARNING: EMOTION SHAPES KEY LEARNING IN LANGUAGE

Overall, Nico and Brooke compensated remarkably well for prosodic capacities, accurately judging speakers' sarcastic and serious intents and producing adequate intonation in their spontaneous speech. However, further analysis revealed that they were using quite atypical strategies to make sense of the story characters' tones of voice and that their own prosodic production was generally exaggerated and unregulated. Specifically, while Nico made snap judgments about speakers' tone and showed little ability to reflect on the source of his judgments, Brooke mused extensively over the speakers' tones and their associated emotions, often bringing his own experiences to bear on the speakers' emotional situations. Both boys also showed distinctly atypical emotional profiles in the SIR interview, with Brooke explaining elaborate and effortful strategies for controlling his negative emotions and Nico seeming to avoid the discussion of emotion altogether. Both Nico and Brooke were moderately accurate at recognizing emotional expressions on faces, although Brooke's errors were less systematic than Nico's, which seemed to follow a predictable error pattern toward judging emotive faces as neutral. In general, these results suggest that, while Nico was avoiding emotion and instead processing affective information in both modalities as something akin to "pseudo-grammatical," memorized categories, Brooke was attempting to solve these problems by reveling in the connections between emotion and tone of voice. In this way, both boys

appear to be compensating by capitalizing on the neuropsychological strengths, including emotional strengths, associated with their remaining hemisphere, rather than by adapting their remaining hemisphere to act as the missing hemisphere would have.

Prosody

Understanding Others' Prosody

Figure 2 presents Nico's and Brooke's scores in relation to the scores of their same-age, same-language peers on the prosodic discrimination tasks. The first three measures involve tasks that are quite linguistic in nature, meaning that they are reliant on analyses of pitch but are not particularly emotional. As we can see, Nico was quite skilled at these tasks, while Brooke generally performed slightly below the mean. This is interesting in that, despite the right hemisphere's strong pitch-processing capabilities, Brooke was unable to effectively compensate for the loss of his left hemisphere in these tasks, likely because of their dissociation from emotion. Nico, on the other hand, was very competent on these tasks, despite the fact that they rely on pitch, normally associated more strongly with the right hemisphere. Together, Nico's and Brooke's results on these relatively straightforward measures hint at a developmental connection between intonation and emotion in these boys, namely that Brooke associates pitch with emotion, while Nico dissociates these two linguistic dimensions.

The second three tasks were story-based conditions, designed to assess the boys' abilities to use pitch information to make social and emotional inferences about a story character's intent. Here, quite an interesting pattern arose. Nico did comparably to his peers on the context and tone conditions. Somehow, he had managed to recognize sarcasm based on tone alone, despite missing the hemisphere that would normally handle sentence-level tone and emotion. Brooke also performed comparably to his peers on the context condition. However, when given only tone of voice information and asked to make inferences about the characters' emotion or social intent, his performance rose to almost two standard deviations above that of his peers, who were themselves very competent. Also, Brooke loved using tone for such a purpose and greatly enjoyed this task. In the last story condition, in which context and tone information needed to be integrated to correctly answer, both Brooke and Nico were impaired.

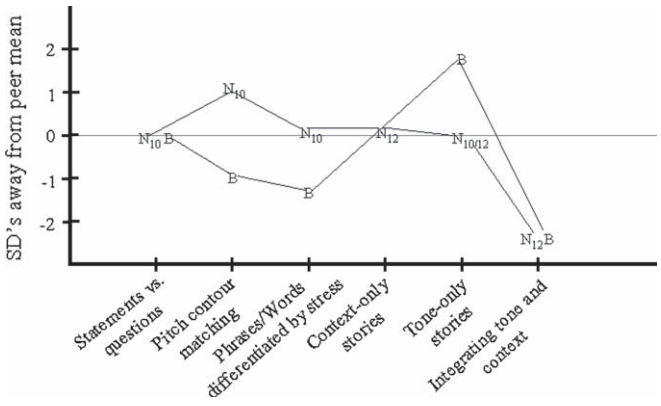

Fig. 2. Nico's and Brooke's prosodic discrimination abilities in standard deviations compared to the means of their same-age, same-language peers. Note. Tests are arranged in approximate order of difficulty from left to right. N_{10} and N_{12} represent Nico at ages 10 and 12, respectively. B represents Brooke at age 18. SD stands for standard deviation. Brooke's score on context-only stories is not included as there was too little variation among scores for the standard deviation to be meaningful (scores ranged from 9 to 10 out of 10, Brooke received a 9).

The results on the three story-based conditions present an intriguing scenario, in which both boys compensated remarkably well on the straightforward context and tone tasks, but neither could handle the two sources of information together. What is more, while Nico performed adequately on the tone task, Brooke excelled at it. Clearly, to make sense of these patterns of performance requires moving beyond assessing the boys' abilities to complete the task, instead examining in more depth their respective social, emotional, and cognitive strategies. That is, upon closer examination, it may be that these tasks present quite different cognitive and emotional problems to Nico and to Brooke and that these different problems may reflect the two boys' compensatory mechanisms.

Therefore, I move to comparing the boys' coded justifications for their answers in the context and tone conditions. Most striking in these results is that, while Nico and Brooke performed somewhat atypically on the context condition stories, they performed very atypically on the tone condition stories. In the context condition, Brooke's strategy profile was different from the comparison boys' only in that he had a slight tendency to extrapolate beyond what was relevant. He also tended to maintain his own perspective more than the comparison boys, at times giving answers such as, "How do I know that? Because I read [sic] the story" or "because I'm psychic." In other ways, his strategies on the context condition stories were quite typical.

However, in the tone condition, a more complex pattern of differences emerged. He now overattributed speaker intentions and used more second-order perspectives than necessary to solve the items. He extrapolated beyond relevant information in 11 out of 13 items and brought his own experiences to bear on the story more than nine times more often than his peers. Most importantly, he directly imitated the story characters' tone of voice in 7 out of 13 items, more than five times more often than his same-age peers. Overall, in the tone condition, while Brooke was highly accurate in judging speakers' intent, he tended to justify his answers by musing and empathizing more than his peers about

story characters' motives, emotions, and tone of voice, often bringing his own experiences to bear on the problem. And, when Brooke worked from tone of voice, he would usually note the emotion that the tone seemed to portray and the implications of that emotion for the story. For instance, in a story in which an older sister sarcastically tells her younger sister, "Yeah, I'm sure you have *lots* of homework!," Brooke responded,

> She was probably joking around. But I think she was serious at the same time. It's like two things at once … joking around is like, "you don't have no homework." [said in a joking tone] That's joking around. Serious is like, "you have homework? That's a drag." [said in an exaggeratedly serious tone] That's serious. So it's like a little mix.

Here, Brooke justified his decision that the story character's intent was sarcastic by talking as the character would sound were she sarcastic or serious and then explaining that the character's original statement was, in his opinion, a mix between these two tones.

For a further example, in describing how he knew that a speaker was lying when she said she had scored 10 soccer goals when in fact she had scored only one in the story, Brooke said,

> She didn't want to admit she only scored one point … And you can't even score 10 points. You can probably only score like 5, and that's the highest you can go. 'Cause I can only—out of a game—I can only score like 2 or 3 and that's if I really try.

In this example, Brooke used his own experience with soccer to guide his judgment, even though the story had plainly stated how many goals the girl had scored.

Nico also made use of atypical answer strategies, especially in the tone condition, but showed a different pattern of answers than Brooke. In the context condition, Nico performed quite similarly to his peers, except for a strong tendency to maintain his own perspective rather than discuss the story characters' perspective. In the tone condition, however, Nico's differences became much more pervasive. He used the general strategy of restating information and talking about story characters' first-order perspectives or tone less often than his peers, failing to consider adequately the story characters' emotions. Rather than discuss a character's feelings, motives, and tone, his favored strategy was to produce accurate, snap judgments of a story character's tone and to avoid speculating about emotional or other implications. For example, he stated several times during the tone conditions, "How do I know that [she is joking]? Because I just heard it." Here, Nico shows no apparent awareness of the source of his judgment, although he was comparably accurate to his peers.

How Nico and Brooke Used Intonation

Given that the neuropsychological substrate for prosodic production has been relatively understudied compared to that for comprehension (Schirmer, Alter, Kotz, & Friederici, 2001), and given the importance of pitch fluctuation to the expression of affective prosody (Pell, 1999; Ross et al., 1997), this portion of the study examined the pitch variation used by Nico and Brooke during the context and tone story conditions above. Each hemispherectomized boy's speech was compared to that from three matched peers.

In general, right hemisphere damage in adults is associated with flattened intonational contours, or monotonic speech (Cohen, Riccio, & Flannery, 1994; Heilman, Leon, & Rosenbek, 2004; Pell, 1999), while left hemisphere damage is associated only with minor affective prosodic difficulties, usually attributed to speech timing rather than to intonational problems (Danly & Shapiro, 1982; Gandour, Petty, & Dardarananda, 1989; Schirmer et al., 2001; Van Lancker & Sidtis, 1992). However, quite surprisingly, I found that both Nico, missing his right hemisphere, and Brooke, missing his left hemisphere, exhibited more intonational variation than their peers. While this was fairly subtle for Nico, Brooke's speech at times sounded hypermelodic, with quite exaggerated and almost humorous intonation, especially when he was enjoying himself. In statistical comparisons between each boy's distribution of utterances, both Nico's and Brooke's mean pitch ranges were significantly higher than those of their peers, and their pitch range distributions were visibly right shifted, at times producing wildly fluctuating utterances unlike anything produced by their peers in this context.

In addition, both boys showed a flattening of their distribution of pitch ranges as compared to their peers, suggesting that they do not have a reliable "unmarked" prosodic state, but rather assign pitch variations to utterances in a less organized or controlled fashion than their peers (see Figures 3a and 3b). While this was dramatic for Brooke, whose intonation flared wildly at times on fairly ordinary utterances, it was more subtly apparent for Nico, who managed to produce a series of utterances that, as a group, approximated quite well those of his peers.

Nico's and Brooke's surprising prosodic production results are likely attributable to developmental compensatory mechanisms not available to brain-damaged adults and provide us with another set of clues as to the two boys' approaches to prosodic and emotional problem solving. In Brooke's case, his strong tendency toward heightened emotionality may be associated with his exaggerated use of intonation, especially because the speech context involved making inferences about others' intentions and emotions based on tone of voice. In Nico's case, tonal language speakers provide a precedent for left-hemisphere analysis of prosodic features (Gandour et al., 2000; Hughes, Chan, & Su, 1983; Moen & Sundet, 1996; Packard, 1986). In tonal languages, such as Mandarin

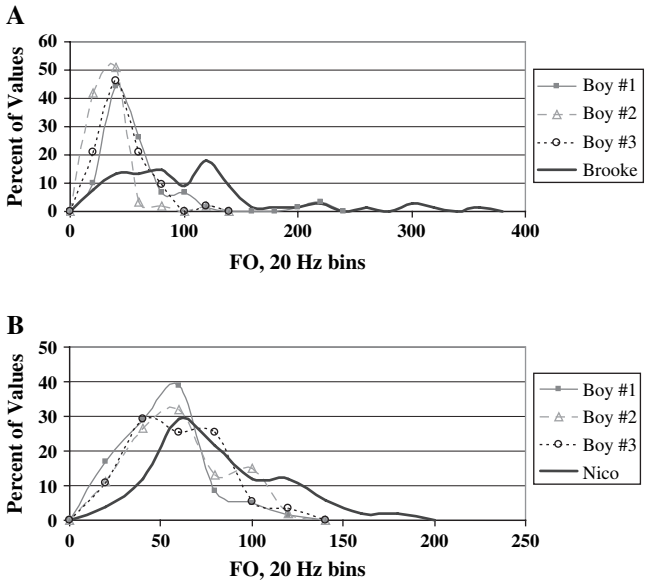

Fig. 3. (a) Distribution of utterance pitch range for Brooke and comparison boys. Note the consistent peak in distribution for the comparison boys at around 40 Hz contrasted to the much flatter distribution for Brooke. Note also the long positive tail on Brooke's distribution. (b) Distribution of utterance pitch range for Nico and comparison boys. Note that while the comparison boys' distributions peak at around 60 Hz, Nico's distribution is visibly right shifted. Note also the long positive tail on Nico's distribution.

Chinese, prosody is used to express both grammatical/lexical information and affective information. In tonal language speakers, while the right hemisphere is heavily recruited for affective prosodic processing, the left hemisphere specializes in processing prosodic grammatical information (Gandour, Ponglorpisit, & Dardarananda, 1992; Gandour, Wong, & Hutchins, 1998), such as to distinguish between words. It is conceivable that Nico has approximated the intonation patterns of the language around him by learning and imitating through a nonaffective, pseudo-grammatical mechanism, in effect that he has memorized particular pitch patterns with affective significance in the same way that a Mandarin speaker memorizes a list of differently intoned words. If this is the case, his hyperprosodic tendencies may be due to overcompensating for a left-hemisphere propensity for flatter intonation, possibly in order to be more socially engaging.

Emotion

Nico and Brooke participated in two complementary assessments of emotion, a clinical-style interview about the participant's thoughts and feelings about his personal relationships with close friends and family, the SIR (Fischer & Kennedy, 1997; Kennedy, 1994), and a conventional assessment of emotion discrimination on faces (Ekman & Friesen, 1975). On both tests, Nico's and Brooke's emotions were atypical; they were less accurate than normals on identifying emotions on faces, and they showed less complex representations of their feelings about close relationships. However, while the boys were atypical, their profiles were also quite distinct from each other. While Brooke showed a sophisticated strategy to actively dissociate negative and positive emotions, Nico seemed equally uncomfortable discussing positive as negative emotions.

The SIR

On the SIR, Brooke showed a distinct reluctance to think or talk about his personal relationships, despite the finding that, in general, adolescents greatly enjoy this interview protocol. He described himself as "gentle and open hearted," but provided only concrete definitions of what these constructs meant, for example, "... open-hearted is like ... you can talk to your friends whenever you want. If you have a problem or something they will understand." When asked to describe his feelings, the only adjectives he spontaneously produced were "happy" and, by way of something negative, "agitated." In talking about his surgery and hospitalization, he used words such as "psycho" (which he clarified as "angry" and produced in the context of explaining how he felt in the hospital after his surgery when he was physically restrained) and "out of control." His descriptions of personal relationships, such as with his best friend Pete, were given begrudgingly and mostly constituted an outright refusal to reflect on relationships. For example, when pushed to talk about what he and Pete enjoy doing together, he replied, "We're just friends. We're not like boyfriend/girlfriend ... I don't know what Pete's real life is! I'm not like the mother of his family."

However, toward the end of the interview, Brooke revealed that he is in fact quite strategic about managing his thoughts and emotions and keeping them exclusively positive. As the conversation worked around again to negative feelings, Brooke explained,

> I put those questions away in the back of my head ... I really don't want to [pull them out] ... It's like a locked door ... All those things you are saying, that I don't want to do, 'cause I try to hide those things. I don't open it up. That's my theory. That's why I'm always happy.

Overall, Brooke's strategy with regard to emotion seemed to be to actively avoid negative emotions at all cost and to effortfully cultivate positive emotional states. He explained, "I just do things that make me happy ... Just got to open up one of those boxes in your head to think about the fun thing you did. And when you are done with your happiness you close the box again to save." In describing how he "gets out of the dumps," he stated, "there's different kinds of methods I

use to get out ... I got to think of it, think of it hard, and sometimes it doesn't click 'til like two hours later."

As these statements reveal, Brooke seemed to modulate his emotions by consciously controlling the situations he allows himself to think about, cultivating positive emotions, and refusing to think about negative emotions. It could be that Brooke's neurological condition has left him less able to modulate or control his own emotional states, a condition that he compensates for by strategically manipulating his thoughts.

While Brooke was quite calculated and reflective in his strategies during the SIR interview, Nico remained very concrete throughout. When asked to describe himself, he stated, "I like to swim" and "I like to travel." The only adjectives for emotional states that he produced were "calm (tranquilo)" in relation to how he feels with his family and "nervous (nervioso)" in school. He seemed to find the interview exceedingly tedious, and his descriptions of his friends and family were very concrete. In addition, he seemed to actively avoid discussing emotional aspects of personal relationships, saying that the task was "too hard." For example, when asked how he feels with his father, he replied, "I don't know, because the truth is that I don't like to go to the cinema and he does. I don't like to go to the cinema a lot." In this answer, rather than reflect even in a simple way on his feelings with his father (as a younger child might), Nico avoided thinking about this relationship and instead turned the discussion toward the concrete topic of the cinema.

Overall, Nico's understanding of emotional states was quite rudimentary and undifferentiated. Although he represented both positive and negative emotions in describing himself, he showed little willingness or ability to further differentiate his feelings.

The Ekman Test of Facial Affect Discrimination

In the Ekman test, Nico and Brooke scored approximately equivalently, with Brooke correctly identifying 71 of 110 photos, or about 65%, while Nico correctly identified 75 photos out of 110, or about 68%. In analyzing responses, surprise and happiness were considered positive emotions, while fear, anger, disgust, and sadness were considered negative.

While Nico was comparatively accurate at recognizing positive emotions like happiness and surprise, he had two major trends in his pattern of errors. First, he tended not to notice the emotions portrayed on faces and to default toward neutrality, at times categorizing emotive faces as "neutral" or "thoughtful [his word]." Second, he tended to make errors distinguishing between negative emotions. In particular, he confused disgust and anger, a mistake common in patients with brain damage (Calder, Keane, Manes, Antoun, & Young, 2000), and had difficulties recognizing sadness. Notably, he never misattributed happiness to a face displaying a negative emotion, and his only error in identifying positive emotions was to mistake happiness for neutrality three times.

The most striking trend in Brooke's data was that he accurately attributed happiness; he labeled the 18 happy photos and only those photos happy. The majority of Brooke's errors were in distinguishing between negative emotions, especially miscategorizing disgust as other negative emotions, mainly anger. Overall, Brooke's errors were sprinkled throughout the exercise and occurred on both emotive and neutral items. Except for his complete failure to recognize disgust and his perfect record in recognizing happiness, Brooke seemed to be less systematic than Nico in his categorization of neutral and emotional faces.

FROM NEUROPSYCHOLOGICAL FINDINGS TO EDUCATIONAL IMPLICATIONS: NEUROPSYCHOLOGICAL STRENGTHS AS BASES FOR ACTIVE TRANSFORMATION IN LEARNING

In juxtaposing measures of affective prosody and emotion in Nico and Brooke, interesting complementary profiles emerge. These profiles provide tentative evidence for a strong developmental relationship between emotion and prosody, one in which the two neuropsychological skills seem to have remained closely associated in both boys through their cognitive and neurological compensation after brain damage. More importantly, though, these complementary profiles provide evidence for a broader trend that, arguably, holds implications for normal children as well. That is, rather than compensating for their extensive brain damage by painstakingly adapting their remaining hemisphere to take over functions normally associated with the missing hemisphere, both Nico and Brooke appear to have instead transformed the nature of the processing problem itself to suit the existing strengths of their remaining hemisphere. Simply put, both boys appear to be compensating so successfully because, instead of changing themselves to suit the problem, they have used their remaining strengths to reinterpret the processing problem itself into something they know how to do. Interestingly, their emotional skills appear to have played a major organizing role in this assimilation process.

The Organizing Role of Emotion

A review of the results demonstrates this trend. In Nico, we see a boy who is very skilled at categorizing affective prosodic information and differentiating statements from questions and sarcastic from sincere tone of voice but relatively poor at explaining what this information implies for the larger social context, such as the outcome of a story. In categorizing emotional faces in the Ekman test, he was passably accurate but tended to regress toward neutrality and had a somewhat difficult time distinguishing between negative emotions. In the SIR

interview, he was similarly uninterested in emotional interpretations, saying that the questions were "hard" and attempting to change the topic of discussion, for instance to the cinema. In each of these results, Nico was relatively efficient at categorizing based on tone or emotion but quite poor at making connections between his judgments and the broader social or emotional contexts that would normally inform them.

How was this possible? Nico, with his left hemisphere intact, seems to have recrafted the emotional and prosodic problems he should not have been able to accomplish into new, fundamentally different, unemotional problems. To do this, he appears to have memorized the relationships between certain tone patterns and their associated emotions, both in his own speech production and in understanding others' speech. This strategy recruits one of the strengths of the left hemisphere, namely categorizing and labeling, such as associating words with meanings. However, it left him relatively impaired at discussing his own emotional relationships and at explaining what his judgments of tone would mean for a speaker's feelings.

Similarly, Brooke drew on the relative strengths of his intact right hemisphere, despite the fact that this left him with various unexpected vulnerabilities. The right hemisphere is generally strong in emotional and pitch processing, skills that Brooke recruited to solve all sorts of problems, whether or not they required it. He often spontaneously brought either emotional or intonational information explicitly to bear, even on basic discriminatory tasks requiring only categorical judgments. For example, in matching a pitch contour to the phrase, "I'm happy to see her," he said, "hmm … she doesn't *sound* happy to see her." In the most complex test, requiring the integration of pitch and stress information with story context, Brooke's strategy was to explicitly describe the tone and pitch patterns in the two choices and then base his judgment on how emotionally or socially appropriate that pitch pattern sounded to him. For example, to one story Brooke responded, "Because [that choice] goes up and then down and then up again. Because it's the anger going on. It sounds meaner, but the other [choice] goes up at the last word, which is nicer." In the SIR interview, Brooke was quite direct about his cognitive strategies for modulating his all-consuming emotions. And in the Ekman facial affect test, he was, if only moderately accurate, highly engaged, often talking as if he actually were expressing the emotion in the picture. For instance, he would use a humorously exaggerated angry voice to label an angry photo or a depressed voice to label sadness. Overall, while Brooke's strategy enabled him to judge tone of voice more accurately than his peers, it also left him liable to serious errors on tasks where emotional interpretation of tone was not relevant, as in the task where utterance pitch contours are matched to contours on blank syllables. His heavy reliance on this strategy also means that he must spend significant effort controlling his emotions, as he described so well in the SIR interview.

Prosody as a Window Into Learning

While the interpretation of the prosodic production analyses is less straightforward, circumstantial evidence suggests that a similar process is at play. Here, both Nico and Brooke flatly defied neuropsychological prediction. Despite the finding that right-hemisphere–damaged patients generally sound somewhat monotonic (Cohen et al., 1994; Heilman et al., 2004; Pell, 1999), Nico used slightly more intonation than he should have, and overall, his utterances looked much like those of his peers. And, despite predictions that Brooke would speak with normal pitch variation, his intonation flared wildly, at times to humorous effect.

One possible interpretation of these findings is that an integration between the brain hemispheres is required in order to adequately modulate pitch and match it to the appropriate emotional intent. Without his right hemisphere, Nico could copy the intonation patterns he hears in his native language, but a careful listener notices that there is something stinted or unspontaneous about his speech. Without his left hemisphere, Brooke produces lots of emotional intonation, but perhaps cannot regulate his production to suit the purpose of his utterance, such as to joke or express emphasis. While an intriguing possibility, this hypothesis could not be adequately addressed with these data, as the utterances in this sample are mainly simple declaratives and therefore do not contain the requisite broad range of affective intents or conversational purposes. However, the preliminary finding that the utterances Brooke and Nico produced with large pitch excursions seem unremarkable for their emotional and conversational intent, unlike the utterances with the widest pitch variations produced by the normal boys, supports this interpretation. For the normal boys, the widest pitch excursions seemed to be associated with either joking or quoting someone else, both of which are known to be accomplished by higher pitch fluctuation (Holt, 1996; Kreuz, 1996). However, Nico's and Brooke's most exaggerated utterances included many simple statements, such as Brooke's "to go to the park" and Nico's "because I just heard it."

Another suggestive piece of evidence comes from preliminary findings, not reported here, about Nico's and Brooke's understanding and production of emotion in their speech, including the ability to understand and express anger, sadness, surprise, happiness, and fear. While Nico could accurately label the emotions in others' speech, he was strikingly impaired at producing or copying emotion on cue, for instance when asked to restate a simple sentence as if he were angry. Brooke too was moderately accurate at recognizing and categorizing emotional prosody. But preliminary results suggest that listeners found his emotional speech, while intensely emotional, difficult to definitively categorize. In this way, Nico may be once again processing emotional speech as if it were categorical, listening for a memorized set of acoustic features and associating them with an emotional label, such as

loudness associated with anger. Conversely, Brooke may be well attuned to the emotion in language but have trouble modulating his prosody to clearly express a particular emotion.

Overall, then, both Nico's and Brooke's profiles on the emotional and prosodic tests suggest a developmental dependency between prosodic and emotional processing and in so doing reveal what could be a basic principle of compensation after brain damage. Nico's rule-bound, categorical approach to prosodic processing leaves him largely unable to use the prosodic information for emotional ends. I would suggest that Nico's left hemisphere, rather than working to understand the affective information as affective, has instead modified the task to suit its relative strength, grammatical or lexical categorization. In effect, Nico may be interpreting different affective tones of voice as categorical rather than emotional information. Conversely, Brooke's apparent heavy reliance on prosody and emotion leaves him vulnerable to emotional regulation problems and to bringing emotional judgments to bear when they are not particularly relevant. Simply put, while both boys' profiles present them with liabilities, each boy seems to be building directly on his comparative neuropsychological strengths, even in the face of compensation for extreme neurological damage. Their approaches to processing reveal that they are bringing their relative strengths to bear and perhaps modifying and specializing these strengths in the learning process, rather than grappling with the processing issue as it is generally perceived.

Insights for Education

Returning to educational considerations, studying Nico and Brooke gives us a glimpse into a possible neuropsychological principle governing learners' active accommodation to and assimilation of their cognitive and emotional environments. While effective educators generally assume that individual learners will approach new problems differently, this work suggests the possibility of an important complementary process as well. That is, in approaching problems from different angles, learners may not simply be bringing different strengths to bear on the same problem but may actually be transforming the intended problem into something new. This implies a need for careful attention to learners' perceptions of the educational problems put to them, as well as a need to design learning environments that capitalize on this process. Students from different cultural and social backgrounds may well interpret the same classroom exercises in very different ways.

For an anecdotal example, in a second-grade math class, I once observed a student confused over the correct answer to a problem about whether a 6-foot-wide car could park in a 7-foot-wide garage. No, it could not, she explained, because the driver would not be able to open the car door. Clearly, although this student's initial response was labeled incorrect, she had indeed solved the math problem correctly but had gone beyond to consider the personal perspective of the driver. While a simple example and one that was quickly resolved, it nonetheless illustrates that this student was considering not simply numbers but practical, personal concerns in solving her math problems.

Another interesting implication of these findings is that, unlike what we might have expected, the hemispherectomized boys' abilities to compensate effectively were not entirely based on the apparent difficulty or complexity of the skill but instead also reflected the social nature of the task. We can see this especially when we compare two of the prosodic receptive conditions: matching the pitch contour of utterances to those on blank syllables and recognizing sarcastic pitch contour in the tone of voice stories. At first glance, and indeed when I designed these conditions, the pitch contour matching was meant to assess the basic level melodic discrimination skills that underlie the sarcasm test. Imagine my surprise, then, when Brooke performed worse and Nico performed better than the comparison boys on this measure! And how could Brooke be so skilled at recognizing sarcasm despite his poor performance on pitch contour matching? The answer led to an interesting insight about the role of emotion and social context in learning, namely that divorcing the skill from its social context changed its very nature and converted it into a problem that Brooke could no longer solve. Nico, of course, found this change made the task easier because he was no longer confounded by social considerations. As educators, we generally assume that isolating a low-level skill will make it more accessible to students and easier, but this example highlights the fact that separating skills from their context can change them in unforeseen ways. To understand how skills function, then, we need to think carefully about how and why the skill is being used in that context, from the student's perspective, and to be mindful about the underlying purpose of the processing. Simpler skills may not necessarily be easier from a neuropsychological perspective. In some cases, students may be able to use complex, contextualized skills in ways that fall apart in stripped-down contexts, even when only the social or emotional context has changed.

Learning as an Active, Emotionally Mediated Process

To conclude, brain development must be viewed as an active process in which learners do not simply assimilate common experiences but instead interpret these experiences actively based on previous learning and innate neuropsychological strengths. Not only is the interpretation process subtle, but it engages social and affective considerations and may be influenced and supported by the particular environment to which a child is exposed. In the cases of Nico and Brooke, we cannot ignore that their successful compensations may be heavily attributable to the highly supportive and personalized educa-

tional environments their families and teachers created for them. Further, Nico's and Brooke's cases suggest that these adaptive interpretations are not limited to so-called "cold" cognition. Rather, affectively and nonaffectively based strategies may at times be interchanged, just as Brooke interpreted all uses of pitch as emotional and Nico avoided emotion in analyzing pitch used for affective tone of voice.

Therefore, while the idea of active, individualized learning is far from new, the study of Nico and Brooke affords us a way to begin to flesh out and embody this principle in brain development and to test and debate its validity. I hope that educators will eventually be able to make use of my conclusions, in combination with those from other interesting examples, to inform their practice in some concrete way, such as helping to shape the design of a curricular intervention or learning environment. However, meeting this goal will require an iterative and difficult process, one that will first involve the integration of many such discussions and examples into a coherent conceptual framework incorporating neuropsychological, developmental, and educational principles. While Nico's and Brooke's results seem on the surface to contradict expectations based on neuropsychological findings with adults, they combine to reveal a compensatory logic that begins to elucidate the active role of the learner as well as the organizing role of emotion in brain development, providing a jumping-off point for discussion between educators and neuroscientists.

Acknowledgments—I am deeply grateful to all those who made this work possible, especially Nico, Brooke, their families, Kurt Fischer, Catherine Snow, Catherine Ayoub, Antonio Battro, Jane Holmes-Bernstein, Michael Connell, David Daniel, and numerous research assistants, particularly Lucia Maldonado. This work was supported by the Spencer Foundation, the American Association of University Women Educational Foundation, the Harvard University Mind Brain and Behavior Initiative, and an anonymous grant.

NOTE

1 Both boys and their families asked that they be identified by their real first names.
2 Thanks to Catherine Ayoub, Harvard University Graduate School of Education, for providing these data to me for the purpose of this analysis.

REFERENCES

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., & Damasio, A. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *Journal of Neuroscience*, *20*, 2683–2690.

Baird, A. A., Gruber, S. A., & Fein, D. A. (1999). Functional magnetic resonance imaging of facial affect recognition in children and adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, *38*, 195–199.

Bates, E., Reilly, J., Wulfeck, B., Dronkers, N., Opie, M., Fenson, J., et al. (2001). Differential effects of unilateral lesions on language production in children and adults. *Brain and Language*, *79*, 223–265.

Bates, E., Thal, D., & Marchman, V. (1991). Symbols and syntax: A Darwinian approach to language development. In N. Krasnegor & D. Rumbaugh (Eds.), *Biological and behavioral determinants of language development* (pp. 29–65). Hillsdale, NJ: Erlbaum.

Battro, A. (2000). *Half a brain is enough: The story of Nico*. Cambridge, UK: Cambridge University Press.

Bloom, L. (1997). Language acquisition in its developmental context. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology: Vol. 2 cognition, perception and language* (5th ed., pp. 309–370). New York: Wiley.

Boatman, D., Freeman, J., Vining, E., Pulsifer, M., Miglioretti, D., Minahan, R, et al. (1999). Language recovery after left hemispherectomy in children with late-onset seizures. *Annals of Neurology*, *46*, 579–586.

Bolinger, D. (1989). *Intonation and its uses: Melody and grammar in discourse*. Stanford, CA: Stanford University Press.

Borod, J. C., Koff, E., Yecker, S., Santschi, C., & Schmidt, J. M. (1998). Facial asymmetry during emotional expression: Gender, valence, and measurement technique. *Neuropsychologia*, *36*, 1209–1215.

Bruer, J. (1997). Education and the brain: A bridge too far. *Educational Researcher*, *26*(8), 4–16.

Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, *3*, 1077–1078.

Campbell, R. (1982). The lateralization of emotion: A critical review. *International Journal of Psychology*, *17*(Suppl. 3), 211–229.

Cancelliere, A. E. B., & Kertesz, A. (1990). Lesion localization in acquired deficits of emotional expression and comprehension. *Brain and Cognition*, *13*, 133–147.

Caramazza, A. (1992). Is cognitive neuropsychology possible? *Journal of Cognitive Neuroscience*, *4*, 80–95.

Case, R. (1996). The role of central conceptual structures in the development of children's thought. *Monographs of the Society for Research in Child Development*, *61*, 1–295.

Case, R. (1997). The development of conceptual structures. In D. Kuhn & R. Seigler (Eds.), *The Handbook of Child Psychology, Vol. 2: Cognition, perception, and language* (5th ed., *Vol. 2*, pp. 745–800). New York: Wiley.

Cohen, M. J., Riccio, C. A., & Flannery, A. M. (1994). Expressive aprosodia following stroke to the right basal ganglia: A case report. *Neuropsychology*, *8*, 242–245.

Compton, R. J., Heller, W., Banich, M. T., Palmieri, P. A., & Miller, G. A. (2000). Responding to threat: Hemispheric asymmetries and interhemispheric division of input. *Neuropsychology*, *14*, 254–264.

Corina, D. P., Bellugi, U., & Reilly, J. (1999). Neuropsychological studies of linguistic and affective facial expressions in deaf signers. *Language and Speech*, *42*, 307–331.

Crystal, D. (1997). *The Cambridge encyclopedia of language* (2nd ed.). Cambridge, UK: Cambridge University Press.

Damasio, A. (1999). *The feeling of what happens*. New York: Harcourt Brace.

Damasio, A. R. (1994). *Descartes error: Emotion, reason and the human brain*. New York: Avon Books.

Danly, M., & Shapiro, B. (1982). Speech prosody in Broca's aphasia. *Brain and Language*, *16*, 171–190.

Deacon, T. W. (2000). Evolutionary perspectives on language and brain plasticity. *Journal of Communication Disorders*, *33*, 273–291.

Diamond, M., & Hopson, J. (1998). *Magic trees of the mind: How to nurture your child's intelligence, creativity, and healthy emotions*. New York: Plume.

Ekman, P., & Friesen, W. V. (1975). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologists Press.

Fischer, K. W., & Bidell, T. R. (1998). Dynamic development of psychological structures in action and thought. In R. M. Lerner (Ed.), *Handbook of child psychology: Theoretical models of human development* (5th ed., Vol. 1, pp. 467–561). New York: Wiley.

Fischer, K. W., & Immordino-Yang, M. H. (2002). Cognitive development and education: From dynamic general structure to specific learning and teaching. In E. Lagemann (Ed.), *Traditions of scholarship in education*. Chicago: Spencer Foundation.

Fischer, K. W., & Kennedy, B. (1997). Tools for analyzing the many shapes of development: The case of self-in-relationships in Korea. In K. A. Renninger & E. Amsel (Eds.), *Processes of development* (pp. 117–152). Mahwah, NJ: Erlbaum.

Gandour, J., Petty, S. H., & Dardarananda, R. (1989). Dysprosody in Broca's aphasia: A case study. *Brain and Language*, *37*, 232–257.

Gandour, J., Ponglorpisit, S., & Dardarananda, R. (1992). Tonal disturbances in Thai after brain damage. *Journal of Neurolinguistics*, *7*, 133–145.

Gandour, J., Wong, D., Hsieh, L., Weinzapfel, B., Van Lancker, D., & Hutchins, G. (2000). A crosslinguistic PET study of tone perception. *Journal of Cognitive Neuroscience*, *12*, 207–222.

Gandour, J., Wong, D., & Hutchins, G. (1998). Pitch processing in the human brain is influenced by language experience. *Neuroreport*, *9*, 2115–2119.

Haidt, J. (2001). The emotional dog and its rational tail: A social intuitionist approach to moral judgment. *Psychological Review*, *108*, 814–834.

Harrington, A. (1991). Beyond phrenology: Localization theory in the modern era. In P. Corsi (Ed.), *Enchanted loom: Chapters in the history of neuroscience* (pp. 207–239). London: Oxford University Press.

Hawley, C. A. (2003). Reported problems and their resolution following mild, moderate and severe traumatic brain injury amongst children and adolescents in the UK. *Brain Injury*, *17*, 105–129.

Heilman, K. M., Leon, S. A., & Rosenbek, J. C. (2004). Affective aprosodia from a medial frontal stroke. *Brain and Language*, *89*, 411–416.

Holt, E. (1996). Reporting on talk: The use of direct reported speech in conversation. *Research on Language and Social Interaction*, *29*, 219–245.

Hughes, C., Chan, J., & Su, M. (1983). Aprosodia in Chinese patients with right cerebral hemisphere lesions. *Archives of Neurology*, *40*, 732–736.

Immordino-Yang, M. H. (2001a). When 2 + 2 makes kids trip: Making sense of brain research in the classroom. *Basic Education*, *45*, 16–19.

Immordino-Yang, M. H. (2001b). *Working memory for music and language: Do we develop analogous systems based on similar symbolic experience?* Unpublished qualifying paper, Harvard University Graduate School of Education, Cambridge, MA.

Immordino-Yang, M. H. (2005). *A tale of two cases: Emotion and affective prosody after left and right hemispherectomy*. Unpublished doctoral dissertation, Harvard University Graduate School of Education, Cambridge, MA.

Immordino-Yang, M. H., & Damasio, A. R. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *Mind, Brain and Education*, *1*, 3–10.

Immordino-Yang, M. H., & Fischer, K. W. (2007). Dynamic development of hemispheric biases in three cases: Cognitive/hemispheric cycles, music, and hemispherectomy. In D. Coch, K. W. Fischer & G. Dawson (Eds.), *Human behavior, learning and the developing brain: Vol. 1. typical development* (pp. 74–111). New York: Guilford.

Jansari, A., Tranel, D., & Adolphs, R. (2000). A valence-specific lateral bias for discriminating emotional facial expressions in free field. *Cognition & Emotion*, *14*, 341–353.

Johnson, M. H. (2000). Cortical specialization for higher cognitive functions: Beyond the maturational model. *Brain and Cognition*, *42*, 124–127.

Kandel, E., Schwartz, S., & Jessell, T. (2000). *Principles of neural science* (4th ed.). New York: McGraw-Hill.

Kennedy, B. (1994). *The development of self-understanding in adolescents in Korea*. Unpublished doctoral dissertation, Harvard University, Cambridge, MA.

Kotz, S. A., Meyer, M., Alter, K., Besson, M., von Cramon, D. Y., & Friederici, A. D. (2003). On the lateralization of emotional prosody: An event-related functional MR investigation. *Brain and Language*, *86*, 366–376.

Kreuz, R. (1996). The use of verbal irony: Cues and constraints. In J. S. Mio & A. N. Katz (Eds.), *Metaphor: Implications and applications* (pp. 23–38). Mahwah, NJ: Erlbaum.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Moen, I., & Sundet, K. (1996). Production and perception of word tones (pitch accents) in patients with left and right hemisphere damage. *Brain and Language*, *53*, 267–281.

Monrad-Krohn, G. H. (1948). Dysprosody or altered 'melody of language'. *Brain*, *70*, 405–415.

Murray, J. P., Liotti, M., Ingmundson, P. T., Mayberg, H. S., Pu, Y., Zamarripa, F., et al. (2006). Children's brain activations while viewing televised violence revealed by fMRI. *Media Psychology*, *8*, 25–37.

National Research Council. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Ohala, J. J. (1984). An ethological perspective on common cross-language utilization of FO of voice. *Phonetica*, *41*, 1–16.

Packard, J. (1986). Tone production deficits in nonfluent aphasic Chinese speech. *Brain and Language*, *29*, 212–223.

Pell, M., & Baum, S. (1997). The ability to perceive and comprehend intonation in linguistic and affective contexts by brain-damaged adults. *Brain and Language*, *57*, 80–99.

Pell, M. D. (1998). Recognition of prosody following unilateral brain lesion: Influence of functional and structural attributes of prosodic contours. *Neuropsychologia*, *36*, 710–715.

Pell, M. D. (1999). Fundamental frequency encoding of linguistic and emotional prosody by right hemisphere-damaged speakers. *Brain and Language*, *69*, 161–192.

Perry, R. J., Rosen, H. R., Kramer, J. H., Beer, J. S., Levenson, R. L., & Miller, B. L. (2001). Hemispheric dominance for emotions, empathy and social behaviour: Evidence from right and left handers with frontotemporal dementia. *Neurocase*, *7*(Pt. *2*), 145–160.

Piacentini, J. C., & Hynd, G. W. (1988). Language after dominant hemispherectomy: Are plasticity of function and equipotentiality viable concepts? *Clinical Psychology Review*, *8*, 595–609.

Reilly, J. S., Bates, E. A., & Marchman, V. A. (1998). Narrative discourse in children with early focal brain injury. *Brain and Language*, *61*, 335–375.

Ross, E. D. (2000). Affective prosody and the aprosodias. In M. Mesulam (Ed.), *Principles of behavioral and cognitive neurology* (2nd ed., pp. 316–331). London: Oxford University Press.

Ross, E. D., Thompson, R. D., & Yenkowsky, J. (1997). Lateralization of affective prosody in the brain and the collosal integration of hemispheric language functions. *Brain and Language*, *56*, 27–54.

Scherer, K. R. (1986). Vocal affect expression: A review and model for future research. *Psychological Bulletin*, *99*, 143–165.

Schirmer, A., Alter, K., Kotz, S., & Friederici, A. D. (2001). Lateralization of prosody during language production: A lesion study. *Brain and Language*, *76*, 1–17.

Schlanger, B. B., Schlanger, P., & Gerstman, L. J. (1976). The perception of emotionally toned sentences by right-hemisphere damaged and aphasic subjects. *Brain and Language*, *3*, 396–403.

Smith, A., & Sugar, O. (1975). Development of above normal language and intelligence 21 years after left hemispherectomy. *Neurology*, *25*, 813–818.

Starkstein, S. E., Federoff, J. P., Price, T. R., Leiguarda, R. C., & Robinson, R. G. (1994). Neuropsychological and neuroradiologic correlates of emotional prosody comprehension. *Neurology*, *44*, 515–522.

Tompkins, C. A., & Flowers, C. R. (1985). Perception of emotional intonation by brain-damaged adults: The influence of task-processing levels. *Journal of Speech and Hearing Research*, *28*, 527–538.

Trauner, D. A., Ballantyne, A., Friedland, S., & Chase, C. (1996). Disorders of affective and linguistic prosody in children after early unilateral brain damage. *Annals of Neurology*, *39*, 361–367.

Trauner, D. A., Nass, R., & Ballantyne, A. (2001). Behavioural profiles of children and adolescents after pre- or perinatal unilateral brain damage. *Brain*, *124*, 995–1002.

Van Lancker, D., & Sidtis, J. J. (1992). The identification of affective prosodic stimuli by left- and right-hemisphere-damaged subjects: All errors are not created equal. *Journal of Speech and Hearing Research*, *35*, 963–970.

Van Lancker-Sidtis, D. (2004). When only the right hemisphere is left: Studies in language and communication. *Brain and Language*, *91*, 199–211.

Voeller, K. K., Hanson, J. A., & Wendt, R. N. (1988). Facial affect recognition in children: A comparison of the performance of children with right and left hemisphere lesions. *Neurology*, *38*, 1744–1748.

Note from the Editors: We have invited several commentaries on this article, including perspectives from cognitive science, neuroscience, and education. They will appear in a future issue.