CHAPTER 13

Transfer of Learning

Concept: Transfer of learning from one performance situation to another is an integral part of skill learning and performance.

After completing this chapter, you will be able to

- Define *transfer of learning* as it applies to the learning of motor skills
- Discuss why transfer of learning is an important concept for motor learning
- Discuss two reasons proposed to explain why transfer occurs
- Define *negative transfer* and relate it to motor skill learning situations
- Discuss the difference between *symmetric* and *asymmetric* bilateral transfer
- Discuss hypotheses that attempt to explain why bilateral transfer occurs

APPLICATION

Why do we practice a skill? One reason is to increase our capability of performing the skill in a situation requiring it. We want to be able to accomplish specific action goals when we need to, whether we perform everyday skills, work skills, or sport skills. For example, if you were a physical therapist working with the gait problems of a stroke patient, you would want that person to be able to walk in environments outside the clinic. The patient should be able to walk at home, in the workplace, at the grocery store, in the mall, etc. Similarly, if you were an athletic trainer, it would be essential for you to prepare the injured athlete you are rehabilitating to perform his or her sport skills in competition. And if you were a basketball coach, you would want your players to play well in games as well as in practice. Each of these examples involves the concept of transfer of learning, because of the need to transfer learned capabilities in one environment or situation to a different environment or situation. In fact, one of the goals of practicing a skill is developing the capability to transfer performance of the skill from the practice environment to some other environment in which the individual must perform the skill so that he or she can achieve the same action goal. Another concern for the practitioner is whether the learning of a new skill will be facilitated or impeded by skills that have already been acquired. A physical educator might wonder whether learning to gallop will interfere with or facilitate learning to skip or whether learning to throw a baseball will influence learning to bowl a cricket ball, for example. Teachers, coaches, and therapists encounter these types of questions frequently.

Application Problem to Solve Select a motor skill that you perform for recreational or sports purposes. When you began learning this skill, what kinds of practice activities did you experience? How well did they prepare you to learn the more complex aspects of this skill? How well did they prepare you to perform this skill in the range of situations and contexts in which you eventually had to perform it, such as in competition or in everyday experiences?

DISCUSSION

Transfer of learning is one of the most universally applied principles of learning in education, sports, dance, and rehabilitation. It rests on the simple premise that all new learning occurs against the backdrop of prior learning. Consequently, prior learning can facilitate, impede, or have no effect on new learning. In educational systems, transfer of learning is an important part of curriculum and instruction development, because it provides the basis for arranging the sequence in which the students will learn skills. In sports and dance, the transfer principle provides the basis for the sequencing of skills that must be learned, the development of drills to perform, and the types of practice experiences athletes need prior to engaging in a game or match and dancers need prior to engaging in a performance. In the rehabilitation clinic, this principle forms the basis for the systematic development of protocols that therapists implement with patients. Because of the widespread importance of transfer of learning, you need to have an understanding of this learning phenomenon as part of your conceptual foundation for studying motor learning.

In chapter 11, we used the concept of transfer of learning when we discussed transfer tests as a method of assessing learning. Those tests are based on the transfer of learning principle. That discussion provided you with a good basis for the present discussion, which will provide you with an understanding of the transfer of learning principle itself.

WHAT IS TRANSFER OF LEARNING?

Learning researchers generally define **transfer of learning** as the influence of previous experiences on performing a skill in a new context or on learning a new skill. This influence may be positive, negative, or neutral (zero). **Positive transfer** occurs when previous experience *facilitates* the learning of a new skill or the performance of a skill in a new context. Each of the examples presented in the Application section at the beginning of this chapter involved positive transfer. **Negative transfer** occurs when previous experience *hinders or interferes with* the learning of a new skill or the performance of a skill in a new context. For example, a person who has learned the forehand in tennis before learning the forehand in badminton often experiences some initial negative transfer for learning the mechanics of the stroke. The badminton forehand is a wrist snap, whereas the tennis forehand requires a relatively firm wrist. The third type of transfer of learning effect is *zero transfer,* which occurs when previous experience has no influence on the learning of a new skill or the performance of a skill in a new context.

Predicting whether transfer will be positive, negative, or zero is difficult. For example, Karen Adolph (1997) found that what infants learned about negotiating risky slopes when they were learning to crawl showed no transfer to negotiating slopes when they started to walk. The infants learned to avoid risky slopes as they accrued crawling experience; however, they plunged head-first down the same risky slopes when they started to walk. In essence, the infants had to learn all over again how to negotiate the risky slopes from their new walking posture. Adolph (1997, 2000) argued that the mapping of perceptual information onto action control strategies was posture specific, with new skills requiring new mappings (see Witherington et al., 2005, for a discussion of the potential limits of this specificity of learning effect). Interestingly, experience with falls, inside and outside the laboratory, did not predict how quickly infants learned to avoid risky slopes when learning to crawl and walk. Rather, some general aspect of crawling experience contributed to the infants' increased skill at determining what slopes they could and could not traverse. Though it is unclear whether these counterintuitive findings generalize beyond the very early development of motor skills, the findings highlight the intriguing nature of the study of motor skill transfer.

WHY IS TRANSFER OF LEARNING IMPORTANT?

We pointed out earlier that the principle of transfer of learning is an important part of educational curriculum development and instructional methodology, the development of pre-competition practices in sports, and the development and implementation of rehabilitation protocols. Thus, from a practical point of view, the transfer principle is very significant for establishing effective motor skills learning environments. But the transfer principle also has theoretical significance, because it helps us understand processes underlying the learning and control of motor skills. The transfer principle has also been central to our understanding of how children acquire more and more complex and context-specific skills during the process of motor development (e.g., see Clark, 2007; Clark & Metcalf, 2002; Kretch & Adolph, 2013).

Sequencing Skills to Be Learned

The sequencing of mathematics skills provides a very useful practical example of the transfer principle as it relates to curriculum development in schools. The curriculum from grades K through 12 is based on a simple-to-complex sequence. Teachers present numeral identification, numeral writing, numeral value identification, addition, subtraction, multiplication, and division in this specific sequence, because each concept is based on the concepts that preceded it. A person presented with a division problem needs to know how to add, subtract, and multiply in order to solve the problem. We do not teach algebra before basic arithmetic. We do not teach trigonometry before geometry.

We can make the same point about skills taught in a physical education program, a sports program, or a rehabilitation clinic. Those who develop a curriculum, program, or protocol should incorporate the transfer of learning principle when they sequence skills. Learners should acquire basic or foundational skills *before* acquiring more complex skills that require mastery of these basic skills. In other words, there should be a logical progression of skill experiences. An instructor should decide when to introduce a skill by determining how the learning of that skill will benefit the learning of other skills. If the instructor does not use this approach, time is wasted while people "go back" to learn prerequisite basic skills.

Using Gentile's Taxonomy to Develop Skill Sequencing

Gentile's taxonomy of motor skills (discussed in chapter 1) provides a good example of how the transfer principle can be implemented in any skill training situation. That taxonomy presents sixteen categories of skills, systematically sequenced from less to more complex according to specific skill characteristics (see table 1.1). We highlighted that one use for the taxonomy was to guide the selection of a functionally appropriate sequence of activities during clinical rehabilitation. Gentile based this taxonomy on the principle of positive transfer. She organized the sequence of activities by listing first the activities that a person must perform before performing more complex or difficult ones. The therapist can select appropriate functional activities for a rehabilitation regime by starting with activities related to the taxonomy category in which the therapist identified the skill performance deficit. Then the therapist can increase activity complexity by progressing through the taxonomy from that point, as described in chapter 1.

Gentile's taxonomy can also be used to develop skill progressions in coaching and physical education contexts. For example, a surfing instructor might

transfer of learning the influence of prior learning on the learning of a new skill or the performance of a skill in a new context.

positive transfer the beneficial effect of prior learning on the learning of a new skill or the performance of a skill in a new context.

negative transfer the negative effect of prior learning on the learning of a new skill or the performance of a skill in a new context.

A CLOSER LOOK

Assessing Positive Transfer of Learning

Researchers commonly use a simple experimental design to determine whether positive transfer has occurred from either (1) experience with one skill to learning another skill or (2) performing a skill in one situation to performing it in another context. The design is as follows:

Experimental group	(1) Practice skill A	Perform skill B
	(2) Perform a skill in context A	Perform the same skill in context B
Control group	No practice	Perform skill B
	No practice	Perform the same skill in context B

The performance score of interest to the researcher is for skill B (1), or context B (2). If positive transfer is evident, then the performance of the experimental group should be better than that of the control group. Thus, prior experience is better than no prior experience for the skill or practice situation of interest.

To quantify the amount of positive transfer, researchers commonly calculate the *percentage of transfer,* which is the percentage of difference between the experimental and control groups' performance scores on skill B or in context B:

$$\textbf{\textit{Percentage of transfer}} = \frac{\text{Experimental group} - \text{Control group}}{\text{Experimental group} + \text{Control group}} \times 100$$

It is important to be aware that a positive percentage will result for all performance measures except those for which a lower value indicates better performance (e.g., error, speed).

use dry land drills when teaching students how to paddle and stand up on a board, before letting them try the skills in the water. The instructor assumes that there will be positive transfer from the dry land drills to the performance of the skills in water.

Künzell and Lukas (2011) provided an illustration of how the transfer principle could be used to facilitate learning to snowboard. Students in an experimental group were given five skateboarding lessons before joining a control group for a six-day snowboarding trip. Expert video-based ratings of performance revealed no significant group differences on the second day of snowboarding practice; however, the students who had received prior skateboarding practice significantly outperformed the control students on the sixth day of practice. Clearly, then, something that was learned during skateboarding practice transferred to snowboarding, though it was interesting to see that the benefits were not realized during the very early days of snowboarding practice.

There are numerous other examples of incorporating the transfer principle in instructional settings. It is common, for example, to practice a part of a skill before practicing the entire skill (we will discuss this practice method in chapter 18). Sometimes an instructor simplifies an activity for a person before requiring the person to perform the skill in its actual context; for example, the coach has a person hit a baseball from a batting tee before hitting a moving ball. If the skill being acquired involves an element of danger, the instructor often allows the person to perform the skill with some type of aid so that the danger is removed. For example, a therapist may initially use a body-weight support system to assist a patient who is relearning to walk but cannot support his or her own body weight while standing. Surgeons commonly train on simulators before engaging in surgery with actual patients as do pilots before their maiden flights. Virtual reality training, an immersive form of simulator training that relies on the transfer of learning principle, is becoming increasingly popular in a range of different contexts, including sports, surgery, rehabilitation, and police and military training. (Note that these and other examples of training methods in which the goal activity is simplified during training will be discussed in chapter 18.)

Assessing the Effectiveness of Practice Conditions

For any instructor, coach, or therapist who wants to determine the effectiveness of a practice routine or instructional method, the rule of thumb should be that *transfer test performance will provide the best assessment.* As you saw in our discussion in chapter 11 concerning the assessment of motor skill learning, a person's performance during practice can over- or underestimate what the person is actually learning. This same principle applies to the assessment of practice routines, skill progressions, and instructional methods. We can know their effectiveness only by determining their impact on performance in the situation for which the practice or instruction was designed to prepare the student, athlete, or patient. For coaches of sports teams, the transfer test is usually the competition for which the athlete or team was preparing. For instructors and therapists, the transfer test is not so easily determined. The instructor or therapist must identify the situations or environments in which the student or patient will need to perform. For the physical education instructor, the test may be performance on a skills test or in a tournament; for a dance instructor the test may be performance in a recital or concert; and for the physical or occupational therapist, the test may be performance of daily living activities at home or work activities in the workplace.

The importance of the transfer test to assess the effectiveness of practice conditions and instructional methods is highlighted by one of the predominant theoretical accounts of why transfer of learning occurs: The *transfer-appropriate processing theory of transfer,* which will be presented later in this discussion, asserts that *the effectiveness of any practice condition should be determined only on the basis of how the practiced skill is performed in a "test" context.* Thus, we should not reach a conclusion about the effectiveness of a practice or instructional strategy until we have observed the person performing the practiced skill in its appropriate test performance situation.

If a person's goal for learning to ride a bicycle is to deliver newspapers, then the greatest amount of transfer between practice and test will occur when the practice experience includes opportunities for throwing a newspaper while riding a bicycle.

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WHY DOES POSITIVE TRANSFER OF LEARNING OCCUR?

The theoretical significance of the concept of transfer of learning becomes evident as we attempt to determine why transfer occurs. For example, if we know why transfer occurs, we have a better understanding of what a person learns about a skill that enables the person to adapt to the performance requirements of a new situation or to learn a new skill.

Although researchers have proposed several reasons over the years to explain why transfer of learning occurs, we will discuss only two of the more prominent hypotheses here. Both consider the *similarities* between the two situations to be critical for explaining transfer. However, they differ in their explanations of which similarities are most important. One hypothesis proposes that

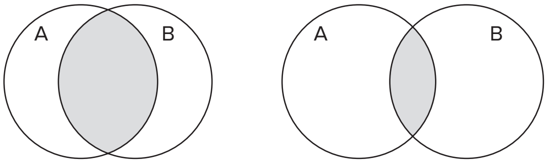

FIGURE 13.1 The two circles (A and B) in this figure can represent two skills or two performance contexts. For either theory proposed to explain why transfer of learning occurs, consider the amount of overlap between the two circles (the shaded area) as representing the degree of similarity between the two skills or performance contexts. More transfer should occur between the two skills or contexts in the set of circles on the left than in the one on the right.

transfer of learning occurs because the components of the skills and/or the context in which skills are performed are similar. The other proposes that transfer occurs primarily because of similarities between the amounts and types of learning processes required (see figure 13.1).

Similarity of Skill and Context Components

The more traditional view of why positive transfer occurs contends that transfer is due to the similarity between the components of two skills or of two performance situations. In this view, the more similar the component parts of two skills or two performance contexts are, the greater will be the amount of positive transfer between them.

An important question concerning the similarity of skill components is this: What constitutes a component part? There are two answers to this question. One is any observable movement part of a skill, such as an overarm movement or a ball striking movement, which could be quantified kinematically. The degree of similarity in the kinematic profiles should provide the most accurate predictions about the potential degree of transfer across skills. For example, both baseball pitching and football passing include overarm throwing movements that are somewhat similar when compared in terms of observable movement, but become decidedly less similar when compared on the basis of their kinematics. The kinematic difference between these skills was nicely demonstrated in a study of high school and college baseball pitchers and football quarterbacks (Fleisig et al., 1996). However, students in a physical education course showed that practicing fundamental overarm throwing for several classes yielded positive transfer benefits for learning both an overhead clear in badminton and the javelin throw (O'Keefe, Harrison, & Smyth, 2007).

Bernstein (1996) had a slightly different take on the components that transfer from one skill to another. He argued that transfer of learning was based on the use of earlier elaborated automatisms. Recall from chapter 12 that automatisms are background corrections to motor skills that can be considered independent skills in their own right. Bernstein thought that the amount of transfer from one skill to another was not based on kinematic similarity but on the similarity of groups of background corrections. For example, he maintained that little transfer would be expected from playing a violin to sawing or filing because of dissimilarities in the required background corrections. Even though the kinematics of the bow, saw, and file may look similar, the forces acting on each implement would be quite different and so the similarity would be achieved by regulating quite different patterns of muscular forces that would require different background corrections. In contrast, Bernstein maintained that transfer would be expected from cycling to ice skating because of similarities in the required background corrections. Although skating and cycling are kinematically dissimilar, the critical feature in both tasks is the need to maintain dynamic balance on a very narrow base of support. Because the forces acting on the body are quite similar, they could be accommodated by regulating similar patterns of muscular forces and using similar background corrections. Bernstein's ideas offer an interesting way to think about transfer of learning, though it is important to point out that his insights on transfer have not been experimentally tested and so remain to be verified.

Task-specific coordination tendencies, such as those we discussed in chapter 5, can also be considered components that transfer from one task to another. For example, from a dynamical systems view of motor control, coordination tendencies and phase relationships that are common between tasks promote positive transfer (e.g., Kelso & Zanone, 2002;

A CLOSER LOOK

Using Virtual Reality to Train Gait in Parkinson's Patients

Mirelman et al. (2011) used virtual reality (VR) as a novel way to train gait in older adults with Parkinson's disease. VR training is an ideal way to deal with the multiple deficits that put Parkinson's patients at much higher risk for falls during walking. Moreover, it permits the therapist to progressively increase the walking challenge by modifying the complexity of the environment in which walking takes place. The main details of the study were as follows:

- Twenty patients received three treadmill training sessions per week for six weeks.
- Patients walked with a safety harness in front of a large screen onto which was projected a scene of a cluttered pathway through a wooded area.
- The task involved walking along the virtual pathway while avoiding a range of different obstacles that moved at different speeds.
- If all obstacles presented in a given trial were cleared the difficulty level was increased to sustain pressure on attention, decision making, and information processing.

Results

- Significant increases in gait speed were seen in usual overground walking with and without obstacles and in walking while performing a secondary task.
- Participants showed decreased gait variability while performing a secondary task, improved cognitive function, and improvements on a range of functional performance measures after the training.
- The gains that were seen immediately after training were retained one month later.

These findings indicate that the combination of treadmill training and virtual reality can significantly improve gait function in people who are at heightened risk for falls during locomotion. Virtual reality training has become increasingly popular in a wide range of different contexts in addition to the rehabilitation clinic. These contexts include surgery, the military, police work, firefighting, search and rescue, and high-performance sports.

Wenderoth, Bock, & Krohn, 2002; Zanone & Kelso, 1997). Interestingly, newly learned patterns of coordination can disrupt patterns that were once stable (Zanone & Kelso, 1992). These findings, according to dynamical systems proponents, suggest that an abstract representation of the underlying coordination dynamics is at the heart of transfer of learning. Further evidence to support this contention comes from the observation that learning a new phase relationship with one set of effectors, such as the arms, will transfer to another set of effectors, such as the legs (Camachon, Buekers, & Montagne, 2004; Kelso & Zanone, 2002). We will address this issue again in the upcoming discussion of *bilateral transfer*.

This similarity of components view has its roots in some of the earliest motor learning research, which was carried out by E. L. Thorndike at Teachers College, Columbia University, in the early part of the 1900s. To account for transfer effects, Thorndike (1914) proposed the **identical elements theory.** In this theory, "elements" are general characteristics of a skill or performance context—such as the purpose of the skill or the attitude of the person performing the skill—or specific characteristics of the skill, such as components of the skill being performed. Additionally, Thorndike considered identical elements to include mental processes that shared the same brain cell activity as the physical action.

According to a *similarity of skill components* comparison, we would expect the amount of transfer between the tennis serve and the volleyball serve to be greater than that between the tennis serve and the racquetball serve. And for a comparison on the basis of the *similarity of context components,* we would

identical elements theory an explanation of positive transfer proposing that transfer is due to the degree of similarity between the component parts or characteristics of two skills or two performance contexts.

A CLOSER LOOK

The Relationship between Practice and Test Contexts Applied to Golf Performance

Golfers and golf teachers often wonder why golfers don't always transfer their performance on the practice range to their play on the golf course. Robert Christina, a motor learning researcher, and Eric Alpenfels, a PGA teaching professional at Pinehurst Country Club in North Carolina, presented an answer to this question in a paper they presented at the World Scientific Congress of Golf in Scotland and published in the proceedings of that meeting (Christina & Alpenfels, 2002). They prefaced their recommendations with the following statement:

> With traditional training (a) students are given immediate feedback or instruction after each swing, (b) they hit balls repeatedly the same distance with the same club from good and level lies, (c) they stroke putts repeatedly from the same distance, (d) they do not rehearse their pre-shot routine, and (e) they do not simulate competitive conditions to practice like they play. We argue that such conditions are likely to produce a level of learning that will enhance performance on the practice range or putting green, but not a level of learning that will enhance its transfer from the practice range to the golf course. Indeed, if the latter prediction is correct, future research also may find that traditional training conditions promote a false sense of confidence in golfers by deceiving them into thinking that the enhanced performance experienced on the practice range will transfer to the golf course when they play the game. (p. 234)

Rather than advocating that golfers stop practicing on the practice range, they suggested that golfers use "transfer training" during practice by simulating the types of experiences they would likely encounter during an actual round of golf. Some specific suggestions were:

- Practice technical and cognitive skills the same way they would be used on the course.
- Practice in a context that simulates the playing context as much as possible. If practice cannot be done on the course, imagine that each practice shot is a specific shot, with a specific purpose, on a specific hole and golf course.
- Instructors should provide feedback less frequently than after every shot as golfers will generally not receive any feedback or instruction when playing.
- Do not hit many shots in a row with one club, but rotate through a sequence of clubs several times.
- Practice around a green just as if playing on the course. Putt the ball until it is holed out rather than from the same spot each time.
- Simulate the competitive pressure that occurs during play on the course as closely as possible during practice (e.g., compete with another player).

expect a higher degree of transfer to occur when practice conditions included transfer test context characteristics than when they do not. In a clinical situation, for example, physical therapy protocols that include walking in the patient's everyday living environment will yield more positive transfer than those that involve experiences only in the clinic.

Similarity of Processing Requirements

The second hypothesis explaining why positive transfer occurs proposes that it results from the *similarity of the cognitive processes* required by the two skills or two performance situations such as when two skills require fast decision making. This hypothesis finds its clearest expression in the view that explains transfer effects in terms of transfer-appropriate processing (see Lee, 1988). This view maintains that although similarity in skill and context components explains some transfer effects, it cannot explain all transfer effects. A key point of the **transfer-appropriate processing theory** is the similarity in cognitive processes required by two performance or learning situations. In this view, transfer is determined by the similarity between the cognitive processing required by the transfer task and the cognitive processing engaged in during training.

Some examples of transfer-appropriate processing include situations where the transfer task requires a person to engage in problem-solving activity, rapid decision making, application of rules, attention control, and the simultaneous performance of two or more tasks. For positive transfer to occur between the training and transfer tasks, the training task also must involve these same types of activities. What is especially important to note here is that the training and transfer tasks do not need to have similar movement components. The critical characteristic is the similarity between the cognitive processing demands of the training task and those of the transfer task.

Merit in Both Hypotheses

Although much remains unknown about the cause of transfer of learning, evidence points to the value of both hypotheses in accounting for transfer effects. As indicated by figure 13.1, we can expect the amount of positive transfer to be related to the amount of similarity between skills and performance contexts. It appears that the similarity-of-processing view is actually an extension of the components view; however, it focuses on processing similarities rather than component or context similarities. But, as Schmidt and Young (1987) concluded in their extensive review of transfer in motor skills, we do not know very much about what accounts for the transfer phenomenon. Unfortunately, research investigating this question has been minimal during recent years, despite the fact that much more research is needed if we are to answer the question of *why* transfer occurs.

NEGATIVE TRANSFER

Although negative transfer effects appear to be rare and temporary in motor skill learning, people involved in motor skill instruction and rehabilitation need to be aware of conditions that may contribute to negative transfer. Because negative transfer effects can occur, it is important to know how to avoid such effects and to deal with them when they occur.

Negative Transfer Situations

Simply stated, negative transfer effects occur when a previously experienced stimulus requires a different response. This means that the *environmental context characteristics of two performance situations are similar, but the movement characteristics are different.* Two situations that are especially susceptible to negative transfer effects involve a *change in the spatial locations of a movement* and a *change in the timing structure of the movement.*

An example of the *spatial location change* occurs when you must drive a car different from your own. Although the brake pedal and accelerator on every car is in the same general location, subtle differences in position have been considered responsible for an effect labeled *unintended acceleration* (Schmidt, 1993). Unintended acceleration occurs when drivers mistakenly apply pressure to the accelerator rather than the brake pedal. The results can be tragic because the driver often panics and presses the accelerator harder and harder in an attempt to stop the car. Another example of a spatial location change for a new experience occurs when people must drive a car on the opposite side of the road to the one they are accustomed to. This situation represents the rearrangement of several spatial locations as now the stick shift, rear-view mirror, and indicator are positioned on opposite sides of the body. Although these objects are familiar, the need is to produce movements that are different from those used previously. The old, familiar movements now interfere with the movements that need to be made. Many drivers have cursed themselves after repeatedly engaging the windshield wipers during attempts to indicate a left- or right-hand turn! These examples demonstrate that when we learn a specific spatially oriented movement to accomplish an action goal, we require attention and time to learn a similar movement that is in a new direction or end location because of the negative transfer effect of the previous learning experience.

The second situation that leads to negative transfer effects involves a *change in the timing structure* of a sequence of movements from a previously learned sequence. Two different types of timing structure conditions are involved here. One is the *rhythmic pattern, or relative time structure,* learned for a sequence of movements. When people learn

transfer-appropriate processing theory an explanation of positive transfer proposing that transfer is due to the similarity in the cognitive processing characteristics required by the two skills or two performance situations.

a specific relative time structure for a sequence of movements, such as when they learn a piece of music, a dance sequence, and the like, and then are asked to perform the sequence and ignore the rhythmic structure they learned, they typically produce the learned rhythmic structure for a number of trials (e.g., Summers, 1975). Freestyle swimmers often encounter this problem when learning the six-beat kick (six kicks for every two arm strokes). Many swimmers naturally employ a two-beat or four-beat kick when learning to swim freestyle. In these swimmers, the lower frequency kick can persist for some time, making the learning of the six-beat kick quite challenging.

The second timing structure condition involves learning the types of phase relationships between limbs that we described earlier in the discussion of coordination dynamics. An example of this situation can be seen in the results of the experiment by Lee, Swinnen, and Verschueren (1995) that was described in chapter 11. Participants were asked to produce a difficult bimanual coordination pattern that varied markedly from their natural coordination tendency, which was to move the arms in temporal synchrony. Recall that after achieving a small amount of progress in performing the new pattern by the end of the first day of practice (refer to figure 11.4), the participants reverted back to producing their natural symmetrical bimanual pattern. Thus the intrinsic coordination tendency to move the arms in temporal and spatial symmetry interfered with the participants' learning of a new asymmetrical movement pattern for the arms.

We often see either of the conditions that induce negative transfer effects when a person tries to "unlearn" a way of performing a skill and learn a new way to perform it. This type of situation occurs in many skill learning contexts. For example, athletes who go from high school to college commonly have to learn to perform a skill in a way that is different from how they performed it in high school. Even though the way they performed it in high school was successful, the college coach knows that to achieve success at the college level, the athlete needs to learn to perform the skill differently. Similarly, in the rehab clinic, physical and occupational therapists often interact with patients who have learned to perform a skill in a certain way because of a disability. For example, a stroke survivor who is several months post-stroke often has acquired a walking gait pattern that distributes force asymmetrically, with more force directed to the unaffected leg, which leads to less time spent on the affected leg in the stance phase of walking. However, the therapist knows that continued performance in this manner will lead to additional physical problems, which means the patient must acquire a different manner of walking than he or she has been using for several months. In these types of situations, people typically show a decrement in performance when they begin practicing the skill in a new way. But with continued practice, performance begins to improve and the new way of moving is produced.

Negative Transfer Effects Are Temporary

In each of the negative transfer situations described in this discussion, a common characteristic has been that the negative effects do not continue through all stages of learning. This is because negative transfer effects are temporary in nature and typically influence skill learning only in the early learning stage. However, it is important for the practitioner to be aware of this characteristic, because the negative transfer effects a person experiences early in practice may discourage a person's interest in pursuing the learning of the new skill or a new way to perform a well-learned skill. In addition, it is important that the practitioner be aware of the aspects of a skill that will be most affected by negative transfer effects and give particular instructional attention to these aspects to help the person overcome these effects.

Why Do Negative Transfer Effects Occur?

There are at least three likely reasons why negative transfer occurs. The first relates to the *memory representation* developed as a result of learning a skill. As a result of performing a skill in one specific way, such as shifting the gear shift in a car with the right hand, a specific perception-action coupling has developed between the perceptual characteristics of the task environment and the motor system. This coupling becomes a part of the memory representation for the action. When a person sees familiar perceptual characteristics in a performance environment, the motor system organizes itself in a preferred way to respond to those characteristics. Although this perception-action coupling allows for fast and accurate performing, it can become problematic when the familiar perceptual situation requires a movement that is different from what was learned. As you have seen in several discussions in this book, to change from the preferred state (i.e., the learned movement for the perceptual event) to a new state is difficult and takes practice.

Another possibility is that negative transfer results from *cognitive confusion.* In the car example, the requirements for driving on the other side of the road undoubtedly lead to some confusion in the driver about what to do. Undoubtedly you have had a similar experience when you have had to type on keyboards that differ in the locations of certain keys, such as the backspace or delete key. When you first begin typing on the new keyboard, you have difficulty striking the keys that are in different locations. What is notable here is that the problem is not with your limb control; you know how to strike keys in a sequence. Rather, the problem is related to the confusion created by the unfamiliar locations of the keys.

The final explanation for negative transfer comes from the dynamical systems perspective. Earlier in the chapter we noted that task-specific coordination tendencies can be considered components that transfer from one task to another. Zanone and Kelso (1992, 1997) have referred to these coordination tendencies as *intrinsic dynamics* (introduced in chapter 12 in the discussion of how established movement patterns are adapted for new purposes). Zanone and Kelso argue that the ease with which new patterns of coordination are learned is a function of whether the learner's intrinsic dynamics cooperate or compete with the dynamics required by the task. Competition between the intrinsic dynamics of the two tasks makes learning the new task more difficult. An intriguing aspect of this explanation for negative transfer is that it predicts what we might call *retroactive negative transfer*, which refers to previously stable patterns of coordination becoming destabilized after a new pattern of coordination has been acquired. Evidence for this type of destabilization was provided by Zanone and Kelso (1992) for a situation in which people learned a novel phase relationship between the two index fingers. This concept is important because it suggests that any new learning will influence a whole range of behaviors connected to the new task. The system-wide changes that occur when infants learn to walk are an excellent illustration of this point. For example, Corbetta and Bojczyk (2002) have shown that infants regress from one-handed to two-handed reaching during the transition to independent walking. Chen, Metcalfe, Jeka, and Clark (2007) showed a temporary disruption of sitting during the transition to walking. Both findings suggest that the coordination tendencies associated with a whole family of skills is reorganized to accommodate the new walking skill.

Fortunately, negative transfer effects can be overcome with practice. You probably have experienced this for either driving or typing, or for both. Just how much practice is required depends on the person and the task itself.

LEARNING HOW TO LEARN AS AN EXAMPLE OF TRANSFER

Learning how to learn can be considered the antithesis of the *specificity of learning* principle introduced in chapter 12 (and to be covered in more detail in chapter 16). The specificity principle asserts that skill acquisition is specific to the tasks that are learned and the contexts in which they are learned. In contrast, learning how to learn suggests that when learners practice multiple types of tasks, they can extract general principles about learning that will transfer to the acquisition of many new tasks. Consider how successful students often navigate their way through high school and university as an example. The successful student doesn't typically succeed by transferring specific knowledge gained in one class to subsequent classes, though that does happen if the curriculum is designed appropriately. Rather, the successful student learns meta-strategies to cope with new material. Such strategies include how to approach new subjects, how to take effective notes, how to study, how to prepare assignments, and how to take exams. If learning is conceived as a form of problem solving, as Bernstein (1967, 1996) maintained, then much can be learned about the nature of problem solving by engaging in the problem-solving process, regardless of the nature of the problems that need to be solved.

Harry Harlow (1949) was the first to introduce the idea of learning how to learn, which he labeled *learning sets*, in a very well-cited review of how animals learn to discriminate object properties. Harlow argued that animals with higher-order intelligence learned to solve new problems quickly by learning patterns within similar classes of previously experienced problems. Karen Adolph (2005) used the learning to learn principle to describe how infants learn to balance as they acquire each new postural milestone. A major problem for the infant learning to balance in a posture like sitting is that the skill must be accomplished on a variety of different surfaces, while concurrently performing various secondary tasks, and against the backdrop of a rapidly changing body. All of the various parameters that can potentially influence sitting represent the problem space, or the class of problems, associated with acquiring skill at controlling that particular posture. Learning to adapt balance to changing constraints is slow and arduous but becomes easier as the infant gains more experience within the problem space. Adolph attributes the lack of transfer from one postural milestone to a new postural milestone (we referred to the lack of transfer from crawling to walking at the beginning of the chapter) to the different sets of problems each posture poses (e.g., Adolph, 1997, 2000). In other words, the learning set that characterizes sitting is very different from the one that characterizes standing.

At the other end of the lifespan, Seidler (2007) has shown that learning how to learn is preserved in older adults. Participants moved a joystick to hit targets on a computer screen with concurrent feedback about the joystick position. One group practiced the original task and learned to adapt to three different rotations of the feedback display about the start location (15, 30, and 45 deg) on their first day of practice. On the second day, they practiced the original task without rotation of the display and adapted to two new task variations—a change in the size of the displayed movements on the screen, and a repeating sequence of movements (up, down, left, right). Two other groups practiced the original aiming task for the same number of trials that the first group practiced all of the rotation variations. On the second day, the other groups either adapted to the changed size of the displayed movement or the repeating sequence of movements. The primary finding was faster adaptation to the new task variations on day 2 by the group that had practiced multiple task variations on day 1. Thus, multiple learning experiences facilitated transfer to the new tasks on day 2 even though the tasks were quite different from the original ones that were practiced. Other researchers have reported that prior participation in a wide range of physical activities or in organized athletics facilitates the learning of new skills (e.g., Boisgontier, Serbruyns, & Swinnen, 2017; Wayne & Miller, 2018).

Interestingly, although learning how to learn has been described as an example of transfer of learning, Seidler (2010) notes that the brain areas that contribute to learning to learn are likely more similar to those associated with early learning than traditional transfer of learning. The early phase of learning sensorimotor adaptation tasks involves the basal ganglia thalamocortical loops, the medial cerebellum, the anterior cingulate cortex, the inferior frontal gyrus, and visual and parietal cortical areas. She hypothesizes that learning to learn involves enhanced contributions from these regions. In contrast, later learning involves the lateral cerebellum, parietal, and cingulated motor areas. She notes that transfer of learning is typically associated with reduced contributions of the early learning network, and overlapping activation with late learning regions.

BILATERAL TRANSFER

When transfer of learning relates to learning of the same task but with the contralateral limb, it is known as **bilateral transfer,** although it is sometimes referred to as *intermanual transfer, cross-transfer,* or *cross-education.* This well-documented phenomenon demonstrates our ability to learn a particular skill more easily with one hand or foot after we already have learned the skill with the contralateral hand or foot.

Experimental Evidence of Bilateral Transfer

Experiments designed to determine whether bilateral transfer does indeed occur have followed similar

LAB LINKS

Lab 13 in the Online Learning Center Lab Manual provides an opportunity for you to experience the bilateral transfer phenomenon.

experimental designs. The most typical design has been the following:

	Pretest	Practice Trials	Posttest
Preferred limb	X	X	X
Nonpreferred limb	X		X

This design allows the experimenter to determine if bilateral transfer to the nonpracticed limb occurred because of practice with the other limb. In the sample experimental design, note that the practice limb is the preferred limb. However, this does not need to be the case; the preferred limb/nonpreferred limb arrangement could be reversed. In either case, the researcher compares pretest-to-posttest improvements for each limb. Although the practiced limb should show the greater amount of improvement, a significant amount of improvement should occur for the nonpracticed limb, indicating that bilateral transfer has occurred.

Investigation of the bilateral transfer phenomenon was popular from the 1930s through the 1950s. In fact, the bulk of the evidence demonstrating bilateral transfer in motor skills can be found in the psychology journals of that period. One of the more prominent investigators of the bilateral transfer phenomenon during the early part of that era was T. W. Cook. Between 1933 and 1936, Cook published a series of five articles relating to various concerns of bilateral transfer, which he called cross-education. Cook terminated this work by asserting that the evidence was sufficiently conclusive to support the notion that bilateral transfer does indeed occur for motor skills.

Given such a foundation of evidence, very few experiments published since those by Cook have focused only on whether bilateral transfer occurs (e.g., Latash, 1999; Nagel & Rice, 2001; Rice, 1998; Weeks, Wallace, & Anderson, 2003). The bulk of the research literature since the 1930s has addressed several issues related to bilateral transfer. Among these are the direction of the greater amount of transfer and the reason bilateral transfer occurs, both of which will be discussed next.

Symmetry versus Asymmetry of Bilateral Transfer

One of the more intriguing questions about the bilateral transfer effect concerns the direction of the transfer. The question is this: Does a greater amount of bilateral transfer occur when a person learns a skill using one limb before learning it with the contralateral limb **(asymmetric transfer),** or is the amount of transfer similar when either limb is used first **(symmetric transfer)**?

Reasons for investigating this question are theoretical as well as practical. From a theoretical perspective, knowing whether bilateral transfer is symmetric or asymmetric would provide insight, for example, into the role of the two cerebral hemispheres in controlling movement. That is, do the two hemispheres play similar or different roles in movement control?

A more practical reason for investigating this question is that its answer can help professionals design practice to facilitate optimal skill performance with either limb. If asymmetric transfer predominated, the therapist, instructor, or coach would decide to have a person always train with one limb before training with the other; however,

bilateral transfer transfer of learning that occurs between two limbs.

asymmetric transfer bilateral transfer in which there is a greater amount of transfer from one limb than from the other limb.

symmetric transfer bilateral transfer in which the amount of transfer is similar from one limb to another, no matter which limb is used first.

A CLOSER LOOK

An Example of Bilateral Transfer for Mirror Writing

Mark Latash (1999) reported a study in which students in his undergraduate class at Penn State University were required to learn a new skill as part of their class experience. The new skill was mirror writing, which involved handwriting a sentence on a piece of paper while looking in a mirror so that it would read correctly in the mirror, not on the paper. Note that this rearrangement of the familiar relation between a motor output and its perceptual consequences is exactly where we'd expect to see negative transfer. During a pretest the students wrote the sentence, "I can write while looking in the mirror," five times with one hand and then the other hand. For each trial, they timed how long it took to write the sentence and counted the errors they made. The students then practiced writing the sentence fifteen times a day, five days a week, for three weeks using the dominant hand only. At the end of the practice period, they did a posttest that required them to perform the task as in the pretest. By comparing the writing performance of the nondominant hand during the pre- and posttests, the students could determine if bilateral transfer resulted from the 225 practice trials with the dominant hand. The results showed that on the posttest for the nondominant hand, they wrote the sentence 40 percent faster than on the pretest, and their errors decreased by 43 percent.

if symmetric transfer predominated, it would not make any difference which limb the person trained with first.

The generally accepted conclusion about the direction of bilateral transfer is that it is *asymmetric*. But there is some controversy about whether this asymmetry favors transfer from preferred to nonpreferred limb, or vice versa. The traditional view has been that there is a greater amount of transfer when a person practices initially with the preferred limb.

Although some controversy continues about this question (see Stöckel & Weigelt, 2012, for an analysis of how some of this controversy might be resolved), there is sufficient evidence to recommend that for most skill training and rehabilitation situations, the greater amount of transfer occurs *from the preferred to the nonpreferred limb* (although see Stöckel, Weigelt, & Krug, 2011, for the opposite effects for children learning to dribble a basketball). This approach not only is consistent with the bulk of the research literature concerned with bilateral transfer, but also is supported by other factors that need to be taken into account, such as motivation. Initial preferred-limb practice has a greater likelihood of yielding the types of success that will encourage the person to continue pursuing the goal of becoming proficient at performing the skill with either limb.

Why Does Bilateral Transfer Occur?

As we saw for explanations proposed to account for positive and negative transfer effects, cognitive and motor control explanations have been offered to answer the question of why bilateral transfer occurs.

The cognitive explanation of bilateral transfer. The *cognitive explanation* states that the basis for the positive transfer from a practiced to a nonpracticed limb is the important cognitive information related to what to do to achieve the goal of the skill, which we described in chapter 12 as an important characteristic of the first stage of learning. This information is relevant to performing the skill regardless of the limb involved. As a result of practice with one limb, the relevant cognitive information is acquired and stored in memory, which then makes it available when the skill is performed with the other limb.

We can relate the cognitive explanation of bilateral transfer to the "identical elements" theory Thorndike proposed, which we discussed earlier. This explanation gives strong consideration to those elements of a skill related to the performer's knowing "what to do." For example, we can consider the performance of a skill with one limb and then the other to be essentially two distinct skills. Throwing a ball at a target using the right arm is a different task from throwing a ball with the left

A CLOSER LOOK

Transfer across Domains

You may be surprised to learn that acquiring a new motor skill influences the development of nonmotor skills in addition to other motor skills. Joseph Campos and his colleagues have provided some of the best illustrations of this principle through their documentation of the profound psychological changes that occur after infants learn to crawl (see Campos et al., 2000, for a review). The onset of crawling heralds a psychological revolution, characterized by broad-scale changes in perception, perceptual motor coordination, spatial cognition, memory, and social and emotional functioning.

Why Do These Changes Occur?

- Changes in psychological function are driven by the pervasive set of new experiences that independent locomotion permits.
- All of these experiences feed into a much deeper understanding of the self, the environment, and the relation between the self and the environment.
- In this sense, crawling per se is not the critical factor in psychological change; rather, new experiences drive psychological development.

Implications

- The relation between crawling and psychological development has enormous implications for children with physical disabilities that impede the development of motor skills.
- Researchers are now beginning to think that at least some of the deficits in psychological function that are often seen in children with physical disabilities are a consequence of impoverished exploratory experiences stemming from the delayed or compromised development of motor skills (Anderson et al., 2013).

arm. However, elements of these skills are common to both, regardless of which hand the thrower is using. Examples include the arm-leg opposition principle for throwing, the need to keep the eyes focused on the target, and the need to follow through. Each of these elements represents *what to do* to successfully throw the ball at a target and does not specifically relate to either arm.

Proponents of this view predict that if a person achieves proficiency at a skill using the right arm, the person does not need to relearn the common cognitive "what to do" elements when he or she begins practicing with the left arm. The person should begin performing with the left arm at a higher level of proficiency than he or she would have had if he or she had never practiced with the right arm.

The motor control explanation of bilateral transfer. The *motor control explanation* for bilateral transfer incorporates the generalized motor program and the dynamical systems theories of motor control as well as our understanding of motor efference in the nervous system. According to the *generalized motor program (GMP) theory,* which we discussed in chapter 5, the muscles involved in the performance of a skill are *not* an invariant characteristic of the GMP. Rather, muscles are a parameter that the person adds to the GMP to allow the achievement of an action goal in a specific situation. As we discussed in chapter 1, action goal achievement can be attained for many motor skills by using a variety of movements. Thus the GMP does not develop as a muscle-specific program to control motor skill performance. This means that the GMP theory predicts that because practicing a skill with one limb establishes the development of a GMP with its invariant characteristics, the skill could be performed with the contralateral limb by applying to the GMP the muscles parameter for that limb.

The *dynamical systems theory* of motor control also provides a basis for bilateral transfer as noted in the previous discussions of intrinsic dynamics. This theory of motor control also states that what is learned is not specific to the limb used to practice

A CLOSER LOOK

Bilateral Transfer Training for Using an Upper-Extremity Prosthesis

For physical therapists who work with patients who will be fitted with, or who recently began wearing, a prosthetic limb on an amputated arm, an important goal is to facilitate the daily functional use of the prosthesis. Research by Weeks, Wallace, and Anderson (2003) provides a training option that is based on bilateral transfer. The training engages patients in the use of a prosthetic simulator with the intact limb. The researchers provided evidence of the effectiveness of this type of training by having non-amputees wear the prosthetic simulator shown in figure 13.2 and practice using it to perform three tasks.

The simulator: It included a figure-8 harness that was fitted around the shoulder contralateral to the prosthesis. It was attached to a cable that ran across the back and upper arm of the limb with the prosthesis. The cable inserted into the proximal end of the simulator and ran the length of the simulator to interface with a split-hook device that was identical to that of a regular prosthesis. The simulator split-hook device was a voluntary-opening device, which means that the wearer opened it by adjusting the tension of the cable with motions of the torso, shoulders, and arm.

The three tasks: Each task began from a common starting point, which was a microswitch button located at the person's midline and 20 cm from the table at which he or she sat. The tasks required the manipulation of various objects at different locations.

1. *Toggle-switch task:* The participant moved the prosthesis 25 cm forward and 20 cm upward to grasp and flip the paddle of a small toggle switch upward. Important in the performance of this task was to grasp the switch, not just flip it without grasping it first.
2. *Fine-aiming task:* The participant was given a stylus (10 cm long, 0.7 cm diameter) and had to place it in a hole directly in front of the start location to activate a microswitch located 2 cm under the task board.
3. *Prehension task:* The participant reached 20 cm laterally and 10 cm forward to grasp a 200 g metallic cylinder (4.2 cm high, 2.8 cm diameter, covered in fine-grain sandpaper) and transport it to the opposite side of the task board and place it in a 3.5-cm diameter target well with a lip 1.5 cm high.

FIGURE 13.2 Upper-limb prosthetic simulator. Courtesy of Stephen A. Wallace.

Marilyn Mitchell

Training: Before being seated at the task table, participants were helped with putting on the simulator. They then watched a video of a model wearing the simulator and demonstrating how to control it. During a second viewing of the video, participants imitated the control motions with the model. They then sat at the task table to begin the following testing protocol:

Pretest: Participants performed five trials of each task with the prosthesis on the transfer arm (i.e., nonpractice arm).

A CLOSER LOOK (*Continued*)

Practice: Participants practiced each task thirty times with the prosthesis on the arm not used for the pretest.
Posttest: Participants performed five trials of each task with the prosthesis on the arm used for the pretest.

Results: Practice benefited bilateral transfer. This was shown in the results by comparing the pretest and posttest performances (movement initial time and movement time) for the control group (performed the pretest and posttest but not the practice trials) with the two bilateral transfer groups (one practiced with the preferred arm, the other with the nonpreferred arm). The bilateral transfer groups showed a greater amount of performance improvement on the posttest with the nonpracticed arm, which demonstrated bilateral transfer from the practiced to the nonpracticed arm. Weeks et al. (2003) are not the only authors to advocate using bilateral transfer in a rehabilitation context.

Results Replicated: It is important to note that an experiment by Ronkema, Bongers, and van der Sluis (2017) replicated the Weeks et al. (2003) study with a more technologically advanced simulator and demonstrated similar bilateral transfer results.

the skill. The dynamical systems theory refers to skill learning as "effector independent," which means that when a motor skill is learned, coordination dynamics are learned without reference to the limb, or limbs, involved in practicing the skill. Rather, what is acquired is an abstract representation of the coordination dynamics. For example, as noted earlier, Kelso and Zanone (2002) showed that participants in an experiment who learned a novel relative phase with their arms or legs transferred those same relative phase characteristics to the nonpracticed pair of limbs. Similar results were reported by Camachon, Buekers, and Montagne (2004) for the transfer between walking and arm movements. It is important to note that although these experiments do not involve bilateral transfer as we have considered it, they demonstrate the effector independence of skill learning and how well people can transfer what is learned to a different set of effectors, which supports the motor control explanation for bilateral transfer.

Evidence of brain interhemispheric transfer of the motor components of tasks has also been used to support the motor control explanation for bilateral transfer (Lee, Hinder, Gandevia, & Carroll, 2010). One way researchers have demonstrated this mediation is by measuring the EMG activity in all four limbs when one limb performs a movement. When EMG activity occurs, it tells researchers that the central nervous system has forwarded commands to those muscles. In fact, research conducted as long ago as 1942 showed that the greatest amount of EMG activity occurs for the contralateral limbs (i.e., the two arms), a lesser amount occurs for the ipsilateral limbs (i.e., arm and leg on the same side), and the least amount occurs for the diagonal limbs (Davis, 1942).

Functional magnetic resonance imaging (fMRI) has also established a neural basis for bilateral transfer. For example, a series of experiments involving the learning of a 12 item finger sequence with the right hand found that the supplemental motor area (SMA) of the cortex had more activity when the skill was performed well with the left hand than when it was performed poorly (Perez et al., 2007). In fact, in one of these experiments when SMA activation was blocked by the use of transcranial magnetic stimulation (TMS), no bilateral transfer occurred. Halsband and Lange (2006) have provided a particularly interesting discussion of the neural basis for bilateral transfer, with an emphasis on the asymmetries in brain activity that are associated with left-to-right and right-to-left transfer.

Which of the two explanations of bilateral transfer is correct? Research evidence indicates that *both cognitive and motor factors are involved in bilateral transfer.* There is no doubt that cognitive components related to "what to do" account for much of the transfer that results from practicing a skill with one limb. This is quite consistent with what we have discussed thus far in this book. For example, both the Fitts and Posner and the Gentile models of the stages of skill learning described in chapter 12 propose that determining "what to do" is a critical part of what a learner acquires in the first stage of learning. There is likewise no doubt that bilateral transfer involves a motor control basis as well. This is consistent with our discussion in chapter 5 of the control of coordinated action. It is also consistent with research evidence that there is some motor outflow to other limbs when one limb performs a skill.

SUMMARY

Transfer of learning concerns the influence of previous experiences on the learning of a new skill or the performance of a skill in a new context.

- The influence of the previous experience may facilitate, hinder, or have no effect on the learning of a new skill or the performance of a skill in a new context.
- The importance of the transfer of learning concept can be seen in its integral role in curriculum development in education, practice conditions in sports contexts, and treatment protocol development in rehabilitation programs.
- The transfer of learning concept is basic to the process of making inferences about the influence of practice conditions and instructional methods on motor skill learning.
- These are two of the hypotheses proposed to account for why positive transfer occurs:
  1. Positive transfer is a function of the similarity of the components of the skills performed and of the environmental contexts in which the skills are performed.
  2. Positive transfer is a function of the similarity of the cognitive processing activities involved in the two situations.
- Negative transfer effects, which are typically temporary and overcome with practice, occur primarily when the familiar relation between a movement and its perceptual consequences needs to be modified.
- Three hypotheses have been proposed to account for why negative transfer effects occur:
  1. The difficulty inherent in altering a preferred perception-action coupling that is well adapted for a specific environmental context.
  2. The initial cognitive confusion that results when a person is not certain about how to move in a familiar environmental context.
  3. Competition between the learner's intrinsic dynamics and the dynamics required by the task.
- Learning how to learn can be considered a form of transfer. Practicing multiple tasks enables learners to extract general principles that can be used to facilitate the learning of new, though typically similar, tasks.
- Bilateral transfer is a phenomenon in which improvement in the performance of a nonpracticed limb results from practice with the contralateral limb.
- Bilateral transfer is typically asymmetric, with the preferred-to-nonpreferred transfer direction yielding greater transfer than vice versa.
- Two hypotheses have been proposed to account for why bilateral transfer occurs:
  1. A cognitive hypothesis proposes that a person applies the knowledge acquired about what to do to perform the skill with one limb to the initial performance of the skill with the contralateral limb.
  2. A motor control hypothesis proposes that the motor control system learns to perform a skill in a non–limb-specific way, which provides the basis for the system specifying a nonpracticed limb to perform the skill at some future time, and the expectation that performance with the nonpracticed limb will be higher than if there had been no practice with the other limb.

POINTS FOR THE PRACTITIONER

- The sequencing of skills or activities should be based on the concept of transfer of learning. This means that each skill or activity benefits from previous skills or activities and will benefit those that follow. Follow the simple-to-complex rule of sequencing skills and activities.
- When teaching motor skills, include practice opportunities in contexts and situations that are, or simulate, the contexts and situations in which people will use the skills in their everyday life, work, or recreation.
- Before developing a program of instruction or rehabilitation, consider the previous motor skill performance experiences the person or people have had. Take advantage of opportunities to allow them to benefit from experiences that promote positive transfer; prepare to help them overcome negative transfer experiences.
- Keep in mind that engaging in the learning process, regardless of the skills that are learned, can have a cumulative effect that benefits the learning of new skills.
- Take advantage of bilateral transfer when working with people who have an injured or impaired limb.
- When teaching a skill that a person should learn to perform equally well with either limb, take advantage of bilateral transfer by beginning practice with the person's preferred limb. After the person has developed a reasonable degree of proficiency performing the skill with that limb, have the person practice with the other limb. Shortly thereafter, have the person alternate practice with each limb.

RELATED READINGS

Aune, T. K., Aune, M. A., Ingvaldsen, R. P., & Vereijken, B. (2017). Transfer of motor learning is more pronounced in proximal compared to distal effectors in upper extremities. *Frontiers in Psychology, 8*(1530). doi: 10.3389/fpsyg.2017.01530

Ausenda, C. D., & Carnovali, M. (2011). Transfer of motor skill learning from the healthy hand to the paretic hand in stroke patients: A randomized controlled trial. *European Journal of Physical and Rehabilitation Medicine, 47,* 417–425.

Betker, A. L., Desai, A., Nett, C., Kapadia, N., & Szturm, T. (2007). Game-based exercises for dynamic short-sitting balance rehabilitation of people with chronic spinal cord and traumatic brain injury. *Physical Therapy, 87*, 1389–1398.

Ferguson, M. C., & Rice, M. S. (2001). The effect of contextual relevance on motor skill transfer. *American Journal of Occupational Therapy, 55,* 558–565.

Gautier, G., Thouvarecq, R., & Larue, J. (2008). Influence of experience on postural control: Effect of expertise in gymnastics. *Journal of Motor Behavior, 40*, 400–408.

Graziado, S., Nazarpour, K., Gretenkore, S., Jackson, A., & Eyre, J. (2015). Greater intermanual transfer in the elderly suggests age-related bilateral motor cortex activation is compensatory. *Journal of Motor Behavior, 47*(1), 46–55.

Hebert, E. P., Landin, D., & Solmon, M. A. (2000). The impact of task progressions on student practice quality and task-related thoughts. *Journal of Teaching in Physical Education, 19,* 338–354.

Issurin, V. B. (2013). Training transfer: Scientific backgrounds and insights for practical application. *Sports Medicine, 43,* 675–694.

Kwon, O., Zelaznik, H. N., Chiu, G., & Pizlo, Z. (2010). Human motor transfer is determined by the scaling of size and accuracy of movement. *Journal of Motor Behavior, 43,* 15–26.

Lam, T., & Dietz, V. (2004). Transfer of motor performance in an obstacle avoidance task to different walking conditions. *Journal of Neurophysiology, 92,* 2010–2016.

Meyer, R. K., & Palmer, C. (2003). Temporal and motor transfer in music performance. *Music Perception, 21,* 81–104.

Obayshi, S. (2004). Possible mechanism for transfer of motor learning: Implication of the cerebellum. *Cerebellum, 3,* 204–211.

Pacheco, M. M., & Newell, K. M. (2018). Transfer of learned coordination function: Specific, individual, and generalizable. *Human Movement Science, 59,* 66–80.

Park, J. H., & Shea, C.H. (2002). Effector independence. *Journal of Motor Behavior, 34,* 253–270.

Ranganathan R., Wieser, J., Mosier, K. M., Mussa-Ivaldi, F. A., & Scheidt, R. A. (2014). Learning redundant motor tasks with and without overlapping dimensions: Facilitation and interference effects. *Journal of Neuroscience, 34,* 8289–8299.

Sanders, R., Li, S., & Hamill, J. (2009). Adjustment to change in familiar and unfamiliar task constraints. *Journal of Sports Sciences, 27*, 651–659.

Shea, C. H., Kovacs, A. J., & Panzer, S. (2011). The coding and inter-manual transfer of movement sequences. *Frontiers in Psychology, 2,* 1–10.

Shields, R. K., Leo, K. C., Messaros, A. J., & Somers, V. K. (1999). Effects of repetitive handgrip training on endurance, specificity, and cross-education. *Physical Therapy, 79,* 467–475.

Stevens, D., Anderson, D. I., O'Dwyer, N. J., & Williams, A. M. (2012). Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills? *Consciousness and Cognition, 21,* 1122–1128.

Strobach, T., Frensch, P., Müller, H., & Schubert, T. (2015). Evidence for the acquisition of dual-task coordination skills in older adults. *Acta Psychologica, 160*, 104–116.

STUDY QUESTIONS

1. Define the term *transfer of learning.* Describe and give an example of the three types of transfer of learning that can occur based on the type of influence of previous experiences.
2. Discuss two reasons why transfer of learning is an important concept in our understanding of motor learning and control.
3. What are two reasons proposed to explain why positive transfer occurs? For each of these, give a motor skill example.
4. What situation characteristics predict negative transfer? Give two motor skill performance examples of these characteristics and indicate why negative transfer would occur in each.
5. What is bilateral transfer? What is the issue underlying the question of whether bilateral transfer is symmetric or asymmetric?
6. Discuss two hypotheses that explain why bilateral transfer occurs.

Specific Application Problem:
Select a motor skill that you might teach in your future profession. Describe two activities or drills that you would use as two sequential preliminary activities before teaching the motor skill. Indicate why you would use each activity or drill and why you would expect positive transfer from each.