CHAPTER 11

Defining and Assessing Learning

Concept: People who assess learning must make inferences from observing performance during practice and tests.

After completing this chapter, you will be able to

- Define and distinguish between the terms *performance* and *learning*
- Identify six general performance characteristics typically observable as motor skill learning occurs
- Describe several different methods to assess motor skill learning
- Discuss two reasons performance during the practice of a motor skill may misrepresent the amount of learning that occurred during practice

APPLICATION

Any practitioner involved in motor skill instruction typically has to provide some type of assessment to determine whether or not the student, athlete, or patient has learned what the practitioner has taught. The following two situations, common in physical education and rehabilitation settings, provide examples of the importance of assessing learning.

Suppose you are a physical educator teaching a tennis unit. If you are teaching your students to serve, how do you determine whether they are actually learning what you are teaching them? What will you look for to assess their progress in learning to serve? How can you be certain that what you are observing is the result of learning and not just luck?

Or suppose you are a physical therapist helping a stroke patient to relearn how to walk without support. What evidence will tell you that this patient is learning to do what you have taught him or her to do? What characteristics of the patient's performance will make you confident that the patient has learned this skill and will be able to walk without assistance at home as well as in the clinic?

Application Problem to Solve Select a motor skill that you might teach to someone in your future profession. What would you expect the person to learn as a result of this experience with you? How would you provide evidence to that person or a supervisor to demonstrate that the skill had been learned? How could you be confident that this evidence meets the criteria established by a definition of learning as it relates to motor skills?

DISCUSSION

In any discussion about the assessment of learning, we need to keep two important terms distinct: *performance* and *learning*. This distinction helps us establish an appropriate definition for the term *learning;* it also helps us consider appropriate conditions under which we should observe performance so that we can make valid inferences about learning.

A CLOSER LOOK

The Terms "Performance" and "Learning"

Performance
- Observable behavior
- Temporary
- May not be due to practice
- May be influenced by performance variables

Learning
- Inferred from performance
- Relatively permanent
- Due to practice
- *Not* influenced by performance variables

PERFORMANCE DISTINGUISHED FROM LEARNING

Simply put, **performance** is *observable behavior*. If you observe a person walking down a corridor, you are observing him or her perform the skill of walking. Similarly, if you observe a person hitting a baseball, you are observing a performance of the skill of hitting a ball. When used in this way, the term *performance* refers to the execution of a skill at a specific time and in a specific situation. *Learning,* on the other hand, cannot be observed directly, but can only be inferred from characteristics of a person's performance.

Before considering a more formal definition for learning, think about how often we make inferences about people's internal states based on what we observe them doing. For example, when someone smiles (an observable behavior), we infer that he or she is happy. When someone cries, we infer that he or she is sad, or perhaps very happy. When a person yawns, we assume that the person is tired. In each of these situations, certain characteristics about the individual's behavior are the basis for our making a particular inference about some internal state we cannot observe directly. However, because we must base our inference on observed behavior, it is possible that our inference is incorrect. For example, if a student sitting beside you in class yawns during the lecture, you might infer from that behavior that the person is tired because of lack of sleep the night before. However, it may be that he or she is bored.

Learning Defined

We will use the following general definition for the term **learning:** *a change in the capability of a person to perform a skill that must be inferred from a relatively permanent improvement in performance as a result of practice or experience.* It is important to note from this definition that the person has increased his or her *capability, or potential,* to perform a skill. Whether or not the person actually performs the skill in a way that is consistent with this potential will depend on the presence of what are known as *performance variables.* These include factors that can affect a person's performance but not the degree of learning the person has achieved. Some examples include the alertness of the person, the anxiety created by the situation, the uniqueness of the setting, fatigue, and so on. When performance variables such as these are present, performance of a skill can misrepresent the amount of learning that has occurred. For example, fatigue can cause a lower level of performance than when the skill is performed without fatigue. As a result, it is critical that methods used to assess learning take factors such as these into account to allow accurate inferences about learning.

GENERAL PERFORMANCE CHARACTERISTICS OF SKILL LEARNING

We generally observe six performance characteristics as skill learning takes place:[1] (a) Improvement; (b) Consistency; (c) Stability; (d) Persistence; (e) Adaptability; and (f) Reduction of attention demand.

[1]These six do not describe all the characteristics associated with skill learning, but highlight those that are most commonly observed. Additional characteristics will be discussed in chapter 12.

performance the behavioral act of executing a skill at a specific time and in a specific situation.

learning change in the capability of a person to perform a skill; it must be inferred from a relatively permanent improvement in performance as a result of practice or experience.

Improvement

First, *performance of the skill shows improvement over a period of time.* This means that the person performs at a higher level of skill at some later time than at some previous time. It is important to note that learning is not necessarily limited to performance improvement. There are cases in which practice results in bad habits, which in turn result in the observed performance's failure to show improvement. In fact, performance actually may become worse as practice continues. But because this text is concerned with skill acquisition, we will focus on learning as it involves improvement in performance. It is also important to note that plateaus and regressions in performance are often seen during skill acquisition, though improvements are apparent when learning is viewed over a longer time scale.

Consistency

Second, as learning progresses, *performance becomes increasingly more consistent.* This means that from one performance attempt to another, a person's performance characteristics should become more similar. Early in learning, performance is typically quite variable from one attempt to another. Eventually, however, it becomes more consistent.

Stability

Although related to the term *variability,* **stability** refers to the influence on skill performance of perturbations, which are internal or external conditions that can disrupt performance. A common internal perturbation is stress, such as is commonly experienced when a person performs a skill under pressure. External perturbations involve environmental conditions that can disrupt performance, such as an obstacle in a person's pathway, the wind, or inclement weather. As learning progresses, performance stability increases. This means that external and internal perturbations have less of an influence on performance. With learning, a person increases the capability to perform the skill despite the perturbations that exist. There are, however, limits to the amount of perturbation that can be overcome.

Persistence

The fourth general performance characteristic we observe during learning is this: *the improved performance capability increases in its persistence.* This means that as the person progresses in learning the skill, the improved performance capability continues (i.e., persists) over increasing periods of time. A person who has learned a skill should be able to demonstrate the improved level of performance today, tomorrow, next week, and so on. The key point here is the term "capability," which as noted earlier, refers to potential, which means that due to the presence of a performance variable the person may not achieve the same performance level on each of these occasions as he or she did at the end of the practice time devoted to the skill. The persistence characteristic relates to the part of our definition of learning that specified that learning involves a *relatively permanent improvement in performance.*

Adaptability

Although not explicitly stated in our definition, an important general characteristic of performance associated with skill learning is that *the improved performance is adaptable to a variety of performance context characteristics.* Some researchers refer to this characteristic as *generalizability,* or how *generalizable* the performance of a skill is. We never really perform a skill when everything in the performance context is exactly the same each time. Something is different every time we perform a skill. The difference may be our own emotional state, the characteristics of the skill itself, an environmental difference such as a change in weather conditions, the place where we perform the skill, and so on. Thus, successful skill performance requires adaptability to changes in personal, task, and/or environmental characteristics. The degree of adaptability required depends on the skill and the performance situation. As a person progresses in learning a skill, his or her capability to perform the skill successfully in these changed circumstances also increases. Later in this book, we will explore some instruction and practice condition characteristics that can influence how well a person adapts to these various situations.

Reduction in Attention Demand

Finally, as you read in chapter 9, motor skills typically demand attention to perform. But, as you will read in more detail in chapter 12, a common change that occurs as a person learns a skill is a reduction in the amount of attention demanded to perform the skill. Researchers commonly demonstrate this demand reduction by using the *dual-task procedure* that was described in chapter 9. As learning progresses, the learner can more easily perform another activity simultaneously. For example, when you learned to ride a bicycle, the attention demands of maintaining control of the bike were high, which made it difficult to converse with another person at the same time. But as you became more skillful at bike riding, you undoubtedly found that your capability to converse with another person increased, especially when you were riding on a straight pathway without people or other vehicles.

LEARNING ASSESSMENT TECHNIQUES

Observing Practice Performance

One way we can assess learning is to record levels of a performance measure during the period of time a person practices a skill. A common way to do this is to illustrate performance graphically in the form of a **performance curve,** which is sometimes referred to as a *learning curve.* This is a plot of the level achieved on the performance measure for each time period, which may be time in seconds or minutes, a trial, a series of trials, a day, etc. For any performance curve, the levels of the performance measure are always on the Y-axis (vertical axis), and the time over which the performance is measured is on the X-axis (horizontal axis).

Performance Curves for Outcome Measures

We can graphically describe performance by developing a performance curve for an outcome measure of performance. An example is shown in figure 11.1, which depicts one person's practice of a complex pursuit tracking task. The task required the person to track, or continuously follow the movement of, a cursor on a computer monitor by moving the mouse on a tabletop. The goal was to track the cursor as closely as possible in both time and space. Each trial lasted about 15 sec. The outcome measure of performance was the root-mean-squared error (RMSE), which was described in chapter 2.

Notice that in this graph you can readily observe two of the four behavioral characteristics associated with learning. First, *improvement* is evident by the general direction of the curve. From the first to the last trial, the curve follows a general downward trend (note that because the performance measure is error, improvement involves decreasing error). Second, we can also see *increased performance consistency* in this graph. The indicator of this performance characteristic is performance on adjacent trials. According to figure 11.1, this person showed a high degree of inconsistency early in practice but became slightly more consistent from one trial to the next toward the end of practice. The expectation would be that the person would increase this consistency with additional practice trials.

General types of performance curves. When a person is learning a new skill, the performance curve for an outcome measure typically follows one of *four general trends* from the beginning to the end of the practice period for a skill. This period of time may be represented as a certain number of trials, hours, days, and so on. The trends are represented by the four different shapes of curves in figure 11.2. Note that in contrast to figure 11.1, the curves in this figure show better performance when they slope upward. Curve *a* is a *linear curve,* or a straight line. This indicates that proportional performance increases over time; that is, each unit of increase on the horizontal axis (e.g., one trial) results in a proportional increase on the vertical axis (e.g., one second). Curve *b* is a *negatively accelerated curve,* which indicates that a large amount of improvement occurs early in practice,

stability the influence on skill performance of perturbations, which are internal or external conditions that can disrupt performance.

performance curve line graph describing performance in which the level of achievement of a performance measure is plotted for a specific sequence of time (e.g., sec, min, days) or trials; the units of the performance measure are on the Y-axis (vertical axis) and the time units or trials are on the X-axis (horizontal axis). This curve is sometimes referred to as a learning curve.

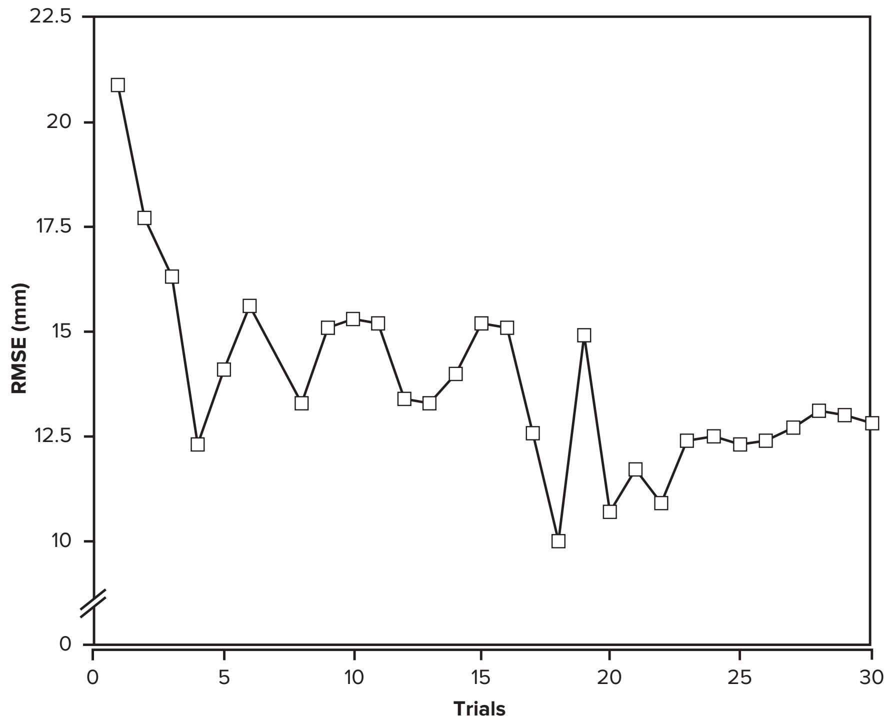

FIGURE 11.1 Performance curve for one person learning a pursuit tracking task. The performance measure is the root-mean-square error (RMSE) for each trial. Notice that because the performance measure is error, lower values represent better performance than higher values.

with smaller amounts of improvement later. This curve is the most prominent type of performance curve for motor skill learning. It *represents the classic power law of skill learning*, which we will discuss in chapter 12. Curve *c* is the inverse of curve *b* and is called a *positively accelerated curve.* This curve indicates slight performance gain early in practice, but a substantial increase later in practice. Curve *d* is a combination of all three curves and is called an *ogive* or *S-shaped curve.*

Each curve in figure 11.2 shows better performance as the curve slopes upward. However, as we noted earlier, there are instances in which the slope of the curve is in a downward direction to indicate performance improvement. This occurs when the performance measure is one for which a decrease in the performance level means better performance. For example, measures involving error (as you saw in figure 11.1) or time (such as speed and reaction time) follow this characteristic as performance is improving when the amount of error or time decreases. In such cases, the directions of the performance curves would be opposite to those just described, although the shapes of the curves would be the same.

It is important to note that the four curves presented in figure 11.2 are *hypothetically smoothed* to illustrate general patterns of performance curves. Typically, performance curves developed for individuals are not smooth but erratic, like the one in figure 11.1. However, there are various statistical procedures that can be used for curve smoothing when the reporting of research results warrants it. Finally, various individual, instructional, and motor skill characteristics can influence the type of curve that will characterize a person's performance as he or she learns a skill. You will learn about several of these characteristics in various chapters of this textbook.

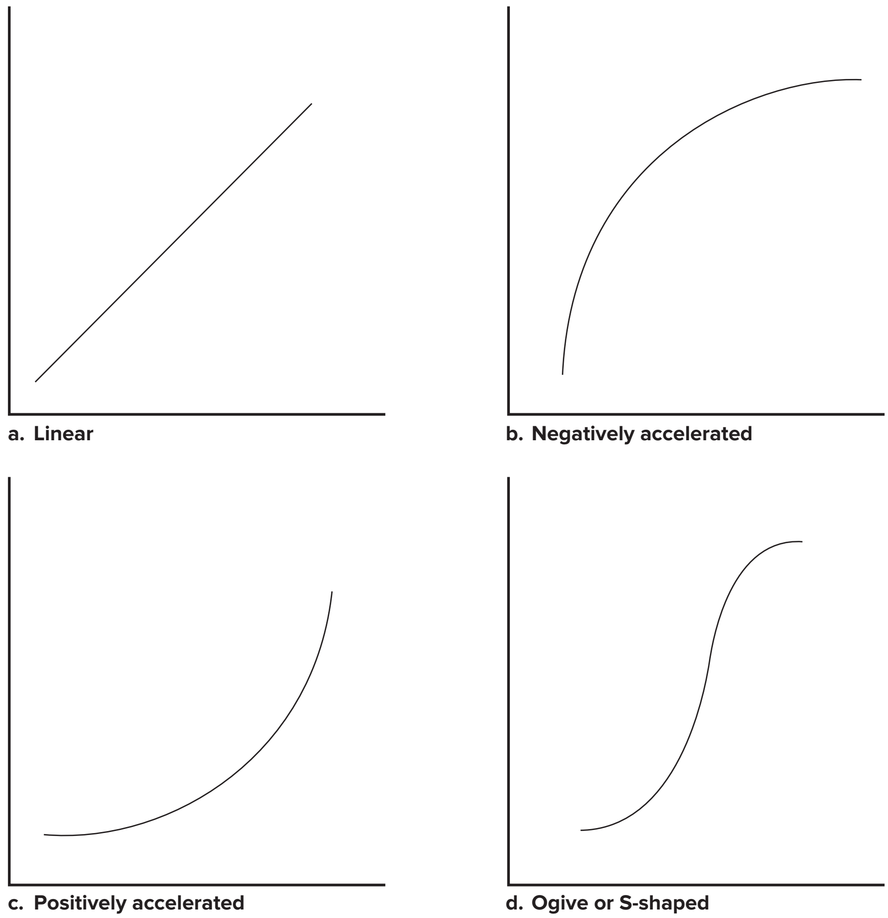

FIGURE 11.2 Four general types of performance curves. Each curve is based on higher performance scores (which would be on the Y-axis or vertical axis) representing better performance than lower scores.

Performance curves for kinematic measures. When we use performance production measures, such as kinematics, we cannot always develop performance curves like the one in figure 11.1. This is the case because a kinematic measure typically does not lend itself to being represented by one number value for each trial. As you learned in chapter 2, kinematic measures involve performance for a period of time *within* a trial. It is important to include this time component in the graphic representation of a kinematic measure.

To assess improvement and consistency in performance for a series of practice trials, researchers commonly show one performance curve graph for each trial or a group (i.e., block) of trials. To show improvement and consistency changes, they depict a representative sample of trials from different stages of practice.

You can see an example of this approach to kinematic measures in figure 11.3. The task required participants to move a lever on a tabletop to produce the criterion movement displacement pattern shown at the top of this figure. Each participant observed the criterion pattern on a computer monitor before attempting to produce it by moving the lever. The four graphs located below the criterion pattern show one person's performance for 800 trials. The graphs show the practice trials in blocks

A CLOSER LOOK

Examples of Motor Skill Performance Adaptability Demands

Closed Skills	
• *Hitting a sand wedge in golf*	• from wet sand, dry sand, etc. • from various locations in the sand trap • to various pin locations on the green • when shot has various implications for score
• *Shooting free throws in basketball*	• one- and two-shot free throws at various times of the game • one-and-one shot situations at various times of the game • with various crowd conditions (e.g., quiet, loud, visible behind the basket) • various types of backboards
• *Walking*	• on various types of surfaces • in various settings (e.g., home, mall, sidewalk) • while carrying various types of objects • alone or while carrying on a conversation with a friend
Open Skills	
• *Hitting a baseball/softball*	• various types, speeds, and locations of pitches • various ball-and-strike counts • various people-on-base situations with various numbers of outs • left-handed and right-handed pitchers
• *Catching a ball*	• balls that are different shapes, weights, sizes, etc. • various speeds and directions • in the air, on the ground • with one or two hands
• *Driving a car*	• various sizes of cars • various street and highway conditions • with or without passengers • various weather conditions

of ten trials each. To demonstrate performance changes during practice, figure 11.3 shows four of the blocks of trials, each representing a different portion of the 800 trial session. Each graph shows two performance characteristics: the person's average (mean) pattern drawn for the block of ten trials (the solid line); and the variability (SD, or standard deviation) of the patterns drawn for the same block of trials (dashed lines).

To determine *improvement in performance,* compare the early to the later practice trials by examining how the shape of the person's produced pattern corresponds to the shape of the criterion pattern. The graphs in figure 11.3 show that as the person practiced more, the produced pattern became more like the criterion pattern. In fact, in trials 751 through 760, the participant was making a pattern almost identical to the criterion pattern.

To assess *changes in consistency,* compare how far the standard deviation lines are from the mean pattern for each block of trials. For trials 1 through 10, notice how far the standard deviation lines are from the mean. This shows a large amount of trial-to-trial variability. However, for trials 751 through 760, these lines are much closer to the mean, indicating that the person more consistently produced the same pattern on each trial of that block of trials.

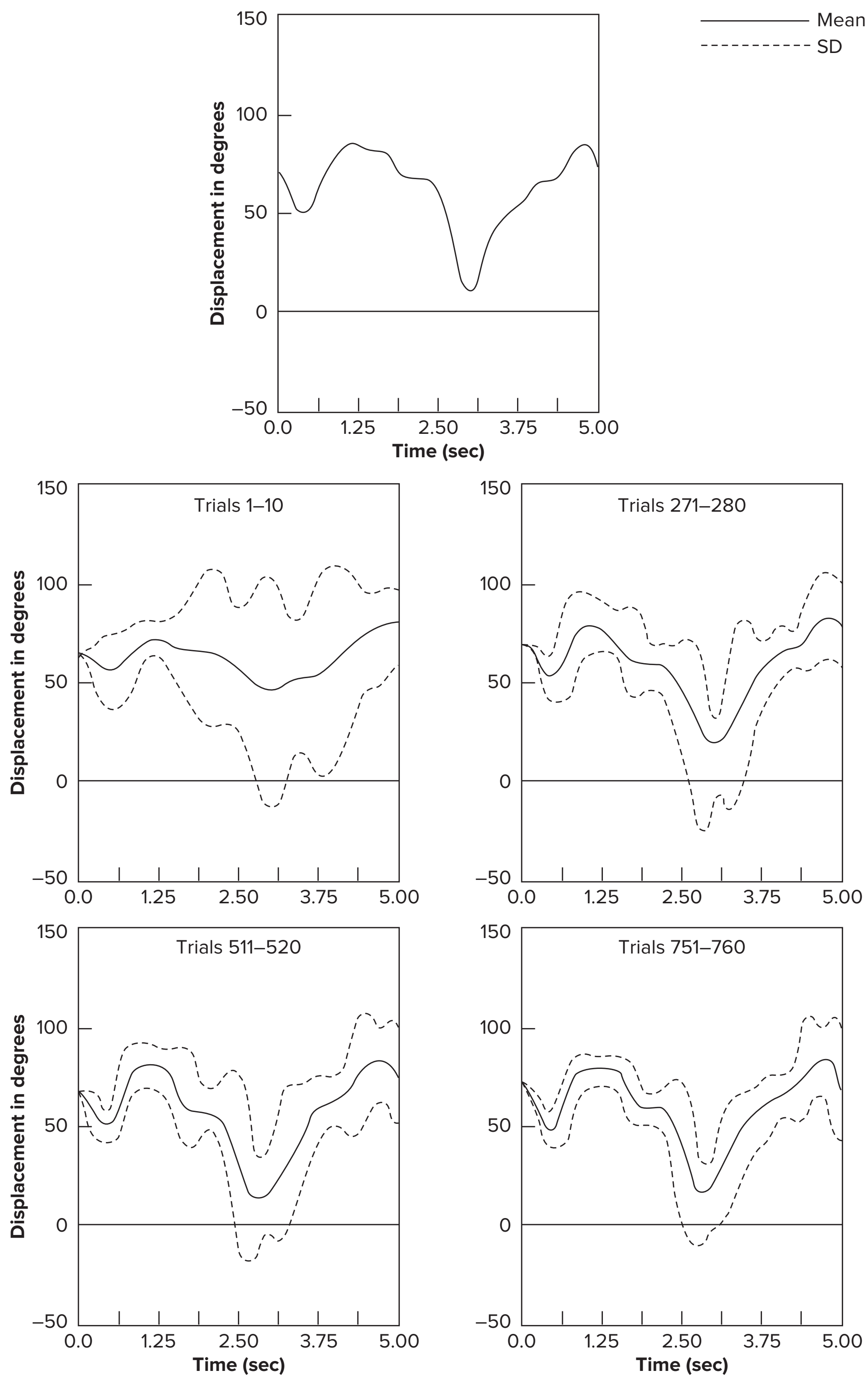

FIGURE 11.3 Results of an experiment by Marteniuk and Romanow showing changes in performance accuracy (displacement) on a tracking task at different practice trial blocks for one participant. The graph at the top shows the criterion pathway for the tracking task. [From Marteniuk, R.G.,& Romanow, S. K. E.(1983). Human movement organization and learning as revealed by variability of movement, use of kinematic information, and Fourier analysis. In R. A. Magill (Ed.), *Memory and control of action.*]

Retention Tests

Another means of inferring learning from performance examines *the persistence characteristic of improved performance* due to practicing a skill. A common means of assessing this characteristic is to administer a retention test. You have been experiencing this approach to assessing learning since you began school. Teachers regularly give tests that cover units of instruction. They use these **retention tests** to determine how much you know, or have retained from your study. The teacher makes an inference concerning how much you have learned about a particular unit of study on the basis of your test performance.

The typical way to administer a retention test in a motor skill learning situation is to have people perform the skill they have been practicing after a period of time during which they have not actually practiced the skill. (Note that this period of time of no practice is sometimes referred to as a *retention interval*, which is a term commonly used in the study of memory.) The purpose is to determine the degree of *permanence or persistence* of the performance level achieved during practice. The actual length of time between the end of practice and the test is arbitrary. But the amount of time should be sufficiently long to allow the influence of any performance variables to dissipate to determine what was learned during practice. The critical assessment is the difference between the person's performance level on the first practice day and on the test. If there is a significant improvement between these two periods of time, then you can be confident that learning has occurred. You will see examples of how researchers have used retention tests to assess learning in the remaining chapters of this book.

Transfer Tests

The third means of inferring learning examines the *adaptability aspect of performance changes* related to learning. This assessment method involves using **transfer tests,** which are tests involving a novel situation to which people must adapt their performance of the skill they have been practicing to the characteristics of this new situation. Researchers have typically used two types of novel situations to assess learning, which practitioners can adapt for their own needs. One is a *new context* in which the people must perform the skill; the other is a *novel variation of the skill* itself. Rather than consider specific examples of how researchers have used various types of transfer tests to assess learning, we will consider how each of these types of novel situations has been used in motor learning research. You will see several specific examples of the use of these types of transfer tests in research studies in the remaining chapters of this book.

One way to assess how well a person learns a serve in tennis is to use a transfer test, such as performing the serve in a tennis match.

Novel context characteristics. Practitioners and researchers can use various kinds of context changes in transfer tests. Context refers to the conditions in which a skill is performed. One context characteristic that researchers have commonly used is to change the *availability of augmented feedback,* which is the performance information a person receives from some external source. For example, in many practice situations, the person receives augmented feedback in the form of verbal information about what he or she is doing correctly or incorrectly. If you were assessing learning to discover how well the person could rely on his or her own resources to perform the skill, then you would like to know how that person would perform without augmented feedback available. For this, an effective context change for the transfer test would be to have no augmented feedback available. It is important to note that some researchers refer to a test that involves this type of context change as a retention rather than a transfer test, because the practiced skill is performed during the test.

Another context characteristic a test administrator can change is the *physical environment* in which a person performs. This is especially effective for a learning situation in which the goal is to enable a person to perform in locations and situations other than those in which he or she has practiced. For example, if you are working in a clinic with a patient with a gait problem, you want that patient to be able to adapt to the environmental demands of his or her everyday world. Although performing well in the clinic is important, it is less important than performing well in the world in which the patient must function on a daily basis. Because of this need, the transfer test in which the physical environment resembles one in the everyday world is a valuable assessment instrument.

The third aspect of context that can be changed for a transfer test is the *personal characteristics* of the test taker as they relate to skill performance. Here, the focus is on how well a person can perform the skill while adapting to characteristics of himself or herself that were not present during practice. For example, suppose you know that the person will have to perform the skill in a stressful situation. A test requiring the person to perform the skill while emotionally stressed would provide a useful assessment of his or her capability to adapt to this situation.

Changes in the environmental context and personal characteristics provide not only opportunities to assess a person's capability to adapt what has been learned, but also opportunities to *assess the stability* of what has been learned. Environmental context changes, such as the presence of other people walking in a hallway or an obstacle in the pathway, can serve as perturbations that might alter the performance of a skill. Requiring a person to perform a skill while emotionally stressed can do the same. The degree to which the person's performance is disrupted by these external and internal perturbations provides evidence of the amount of performance stability a person has acquired as a result of practice.

Novel skill variations. Another aspect of adaptability related to skill learning is a person's capability to successfully perform a novel variation of a skill he or she has learned. This capability is common in our everyday experience. For example, no one has walked at all speeds at which it is possible to walk. Yet, we can speed up or slow down our walking gait with little difficulty. Similarly, we have not grasped and drunk from every type of cup or glass that exists in the world. Yet when we are confronted with some new cup, we adapt our movements quite well to the cup characteristics and successfully drink from it. These examples illustrate the importance to people of producing novel variations of skills. One of the ways to assess how well a person can do this is to use a transfer test that incorporates this movement adaptation characteristic.

Note that one of the methods that can be used to get people to produce a novel skill variation is to alter the performance context in some way so that they must adapt their movements to it. In this way, the transfer test designed to assess capability to produce novel skill variations resembles a transfer test designed to assess capability to adapt to novel performance context features. The difference is the learning assessment focus.

retention test test of a practiced skill that a learner performs following an interval of time after practice has ceased.

transfer test test in which a person performs a skill that is different from the skill he or she practiced or performs the practiced skill in a context or situation different from the practice context or situation.

Coordination Dynamics

Another method of assessing learning involves the observation of the stabilities and transitions of the dynamics of movement coordination related to performing a skill. According to this approach, when a person begins to learn a new skill, he or she is not really learning something new, but is evolving a new spatial and temporal coordination pattern from an old one. When viewed from this perspective, learning involves the transition *from the initial movement coordination pattern (i.e., the intrinsic dynamics), represented by a preferred coordination pattern the person exhibits when first attempting the new skill, to the establishment of the new coordination pattern.* (For detailed discussions see Kostrubiec, Zanone, Fuchs, & Kelso, 2012; Tallet, Kostrubiec, & Zanone, 2008; and Zanone & Kelso, 1994.) We will discuss the concept of intrinsic dynamics again in chapters 12 and 13. *Stability and consistency* of the coordination pattern are important criteria for determining which coordination state (initial, transition, or new) characterizes the person's performance.

For example, a person who is learning handwriting experiences an initial state represented by the coordination characteristics of the upper arm, forearm, and hand while engaged in handwriting at the beginning of practice. These characteristics make up the preferred spatial and temporal structure the person and the task itself impose on the limb, so the limb can produce movement approximating what is required. This initial stable state must be changed to a new stable state in which the person can produce fluent handwriting. Learning is the process that occurs during the transition between these two states and during the development of the consistency and stability of the new state.

An excellent example of this approach to assessing skill learning is an experiment by Lee, Swinnen, and Verschueren (1995). The task (see figure 11.4) required participants to learn a new asymmetric bimanual coordination pattern. (We briefly considered in chapter 7 the motor control difficulties associated with these types of tasks.) To perform the task, they simultaneously moved two levers on a tabletop toward and away from the body at the same rate (15 times in 15 sec). Their goal was to produce ellipses on the computer monitor. To accomplish this, they had to coordinate the movement of their arms so that the right arm on each cycle was always 90 degrees out-of-phase with the left arm. Recall from the discussion of relative phase in chapter 2 that this means that the position of the right arm's lever at any point in time had to be 90 degrees different from the position of the left arm's lever. For example when the left arm's lever was at 0°, the right arm's lever had to be at 90°. This 90-degree difference had to be maintained throughout the 15 sec of movement.

The initial coordination pattern for the two arms for one participant is shown in figure 11.4 as the arm-to-arm displacement relationship performed on the pretest. The diagonal lines seen in the day 1 (pretest) graph were the result of the person moving the arms in-phase. The consistency of this coordination pattern is indicated by the amount of overlap of the fifteen diagonal lines produced during the pretest. Notice the person's tendency to produce that same diagonal pattern on the pretest trial on day 2, after having performed sixty practice trials of the ellipse pattern on day 1.

By the end of day 3, this person had learned to produce the ellipse pattern. Evidence for this is the consistent production of fifteen ellipses in both the pretest and the posttest trials on day 3. However, notice the instability of the performance in the many trials between the old and the new stable patterns (exhibited on the day 1 pretest and the day 3 posttest). This instability occurs during the transition between two stable states and characterizes the process of learning a new skill.

LAB LINKS

Lab 11 in the Online Learning Center Lab Manual provides an opportunity for you to experience the influence of a performance variable during practice as you learn a new motor skill.

Dual-Task Procedure

You read in chapter 9 that the dual-task procedure is commonly used to assess attention demands of activities or tasks. Because attention demands are

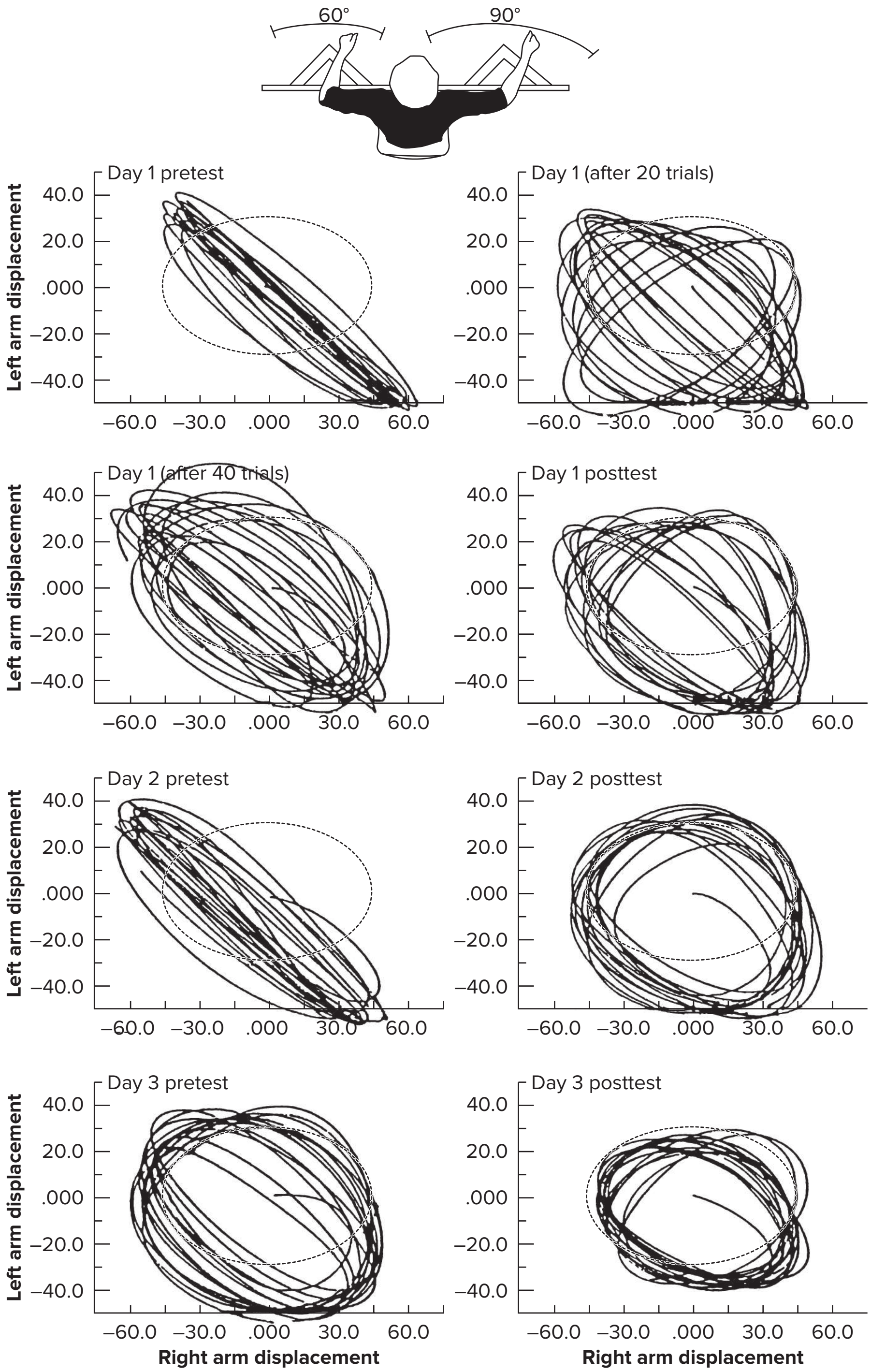

FIGURE 11.4 The task and results from the experiment by Lee, Swinnen, and Verschueren. The top panel shows the task, in which participants moved two levers to draw ellipses on the computer monitor (the dotted lines on each graph represent the goal ellipse pattern). The series of graphs shows the results as the left-arm × right-arm displacements of one person for the pretest and posttest (and some intermediate) trials for each of three practice days. [From Lee, T. D., et al. (1995). Relative phase alterations during bimanual skill acquisition. *Journal of Motor Behavior, 27,* 263–274.]

A CLOSER LOOK

An Example of Practice Performance That Misrepresents Learning

An experiment by Winstein et al. (1996) is a good example of how practice performance may not represent the influence of a variable on the learning of a motor skill (see figure 11.5).

- **Purpose of the experiment:** Which of three different knowledge of results (KR) conditions would be best as an aid to help people learn a partial-weight-bearing task? This task is a skill often taught by physical therapists. (KR refers to performance-outcome information a person receives from a source external to himself or herself.)
- **The task:** The participants' goal was to learn to support 30 percent of their body weight while stepping on a floor scale with a preferred leg while on crutches. The target amount of weight was marked on the scale for each person. Participants in one group could see the scale needle move as they were stepping on the scale (concurrent KR). These participants were able to correctly adjust their weight on each trial. Two other groups received augmented feedback after performing the task (terminal KR). Participants in these groups could not see the scale needle during each trial, but saw a red line on the scale after completing one trial or a five-trial set (the five-trial group saw five red lines, each marked with the corresponding trial number of the set).
- **Practice trials and retention test:** All three groups performed eighty practice trials on one day. Two days later, they performed a retention test[2] that consisted of twenty trials without any KR about the amount of weight they applied to the scale.
- **Results:** *During the practice trials* the concurrent KR group performed with very little error. The two terminal KR groups performed with significantly more error than the concurrent group. However, *on the retention test* the concurrent group performed significantly worse than at the end of the practice trials and worse than both of the terminal groups. The terminal feedback groups performed with about the same amount of error as they produced at the end of the practice trials.

[2]It is important to note that the authors of this article referred to this test as a "retention" test. However, as described in this chapter, it should have been called a "transfer" test, because an environmental context feature (i.e. the availability of augmented feedback) was changed during the test.

- **Conclusion:** It is important to notice that if the retention test had not been given, the conclusion about the best KR condition for learning this task would have favored the concurrent condition. However, this conclusion would be based on performance when the various types of KR were available to the participants. The more valid way to determine which feedback condition is best for learning is when no KR is available, because it reflects the therapy goal of enabling people to perform the partial-weight-bearing task in daily living conditions, which is with no augmented feedback. When the participants were tested under this condition on the retention test, the conclusion was that the *concurrent KR was the worst learning condition.* Thus, performance during practice misrepresented the influence of the KR conditions on learning.

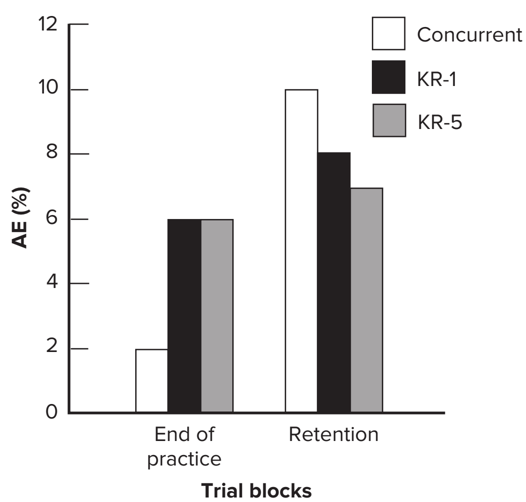

FIGURE 11.5 Results of the experiment by Winstein et al. (1996) showing that performance during practice can misrepresent learning. The graph shows that during practice the group who received augmented feedback concurrently performed better than the other two groups. But on the retention test, this concurrent feedback group's error increased to a level that was worse than that of the other two groups. [From Winstein, C. J. et al. (1996). Learning a partial-weight-bearing skill: Effectiveness of two forms of feedback. *Physical Therapy, 76,* 985–993.]

important in the learning of motor skills, the dual-task procedure can be a means of determining if changes in attention demands for a skill change as a learner becomes more skillful, which, according to Kahneman's theory, is predicted as a characteristic of learning. Because of this expected change, we would assume that we could assess changes in attention demands of a skill or task as a means of assessing learning. Research evidence supports this expectation. For example, Gabbett, Wake, and Abernethy (2011) demonstrated that, for a fundamental rugby skill (the draw and pass), attention demands are lower for high-skilled than lesser-skilled players. In the experiment, the researchers engaged players in a standard drill involving the skill. The dual-task procedure required players to verbally respond as quickly as possible to the frequency level of a tone (high, mid, or low) they heard while they performed the draw and pass skill.

PRACTICE PERFORMANCE MAY MISREPRESENT LEARNING

An important reason for assessing learning on the basis of the types of tests and situations just described is that it may be misleading to base an inference about learning solely on observed performance during practice. There are at least two reasons for this. One is that the practice situation may involve a performance variable, which was described earlier in this discussion as having the potential to artificially inflate or depress performance. The second reason is that practice performance may be misleading if it involves performance plateaus.

Practice Performance May Overestimate or Underestimate Learning

In this textbook, you will see examples of variables whose presence during practice influences performance in such a way that performance overestimates or underestimates learning. One way to overcome these problems is to use retention or transfer tests to assess learning. If a person's practice performance does represent learning, then that person's performance on a retention test should demonstrate the persistence characteristic and not deviate too much from his or her performance at the end of practice. Similarly, transfer test performance should demonstrate the person's increased capability to adapt to novel conditions.

An example of research that demonstrates the use of a transfer test to show the overestimation of practice performance is by Winstein and her colleagues (Winstein et al., 1996), which is described in the "A Closer Look" box on p. 268. Although the experiment investigated an augmented feedback issue, the results showed that an incorrect conclusion about learning effects would have occurred without the use of a transfer test (although the authors referred to it as a retention test).

Performance Plateaus

Over the course of learning a skill, it is not uncommon for a person to experience a period of time during which improvement seems to have stopped. But for some reason, at some later time, improvement starts to occur again. This period of time during which there appears to be no further performance improvement is known as a **performance plateau.**

Examples of performance plateaus are difficult to find in the motor learning research literature because most of this research presents performance curves that represent the average for a group of participants. To find evidence of a performance plateau, individual participants' results are needed. An experiment reported by Franks and Wilberg (1982) is an example of this latter case, and it provides a good illustration of a performance plateau (figure 11.6). This graph shows one individual's performance on a complex tracking task for ten days, with 105 trials each day. Notice that this person showed consistent improvement for the first four days. Then, on days 5 through 7, performance improvement stopped. However, this was a temporary characteristic; performance began to improve again on day 8 and the improvement continued for the next two days. The

performance plateau while learning a skill, a period of time in which the learner experiences no improvement after having experienced consistent improvement; typically, the learner then experiences further improvement with continued practice.

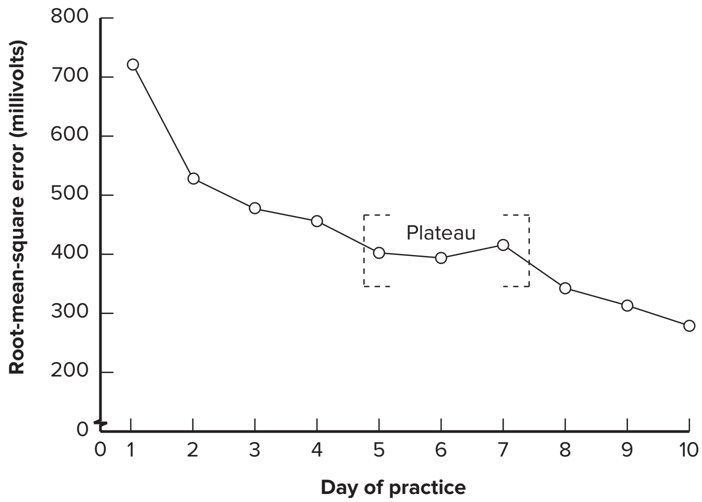

FIGURE 11.6 Results from the experiment by Franks and Wilberg showing the results from one participant performing the complex tracking task for ten days, with 105 trials per day. Notice the performance plateau for three days (days 5, 6, and 7) where performance leveled off before the subject showed improvement again. [From Franks, I. M., & Wilberg, R. B. (1982). The generation of movement patterns during the acquisition of a pursuit tracking task. *Human Movement Science, 1,* 251–272.]

steady-state performance on days 5 through 7 is a good example of a performance plateau.

The concept of a performance plateau has a historical place in motor learning research. The first evidence of a plateau during skill learning is attributed to the work of Bryan and Harter (1897), who published their observations of new telegraphers learning Morse code. The authors noted steady improvement in the telegraphers' letters-per-minute speed for the first twenty weeks. But then a performance plateau occurred that lasted six weeks; this was followed by further performance improvement for the final twelve weeks. Since this early demonstration, researchers have been debating about whether a plateau is a real learning phenomenon or merely a temporary performance artifact (see Adams, 1987, for the most recent review of plateau research). At present, most agree that *plateaus are performance rather than learning characteristics.* This means that plateaus may appear during the course of practice, but learning continues during these times.

There are several *reasons performance plateaus* occur. One is that the plateau represents a period of transition between two phases of acquiring certain aspects of a skill. During this transition, the person is developing a new strategy that the task requires to increase the level of performance already achieved. Consequently, no performance improvement occurs until the new strategy is successfully implemented. Other possible explanations for a performance plateau may be that it represents a period of poor motivation, a time of fatigue, or a lack of attention directed to an important aspect of a skill. Finally, it is possible the plateau may be due not to these performance characteristics but to limitations imposed by the performance measure. This is the case when the performance measure involves what are known as *ceiling* or *floor effects.* These effects occur when the performance measure will not permit the score to go above or below a certain point such as when there is a minimum amount of time in which something can be performed (i.e., a floor effect), or a maximum score that can be attained (i.e., a ceiling effect).

SUMMARY

- To effectively study concepts and issues related to the learning of motor skills, it is important to distinguish the terms *performance,* which is an observable behavior, and *learning,* which is inferred from the observation of performance.
- People typically demonstrate six general performance characteristics as they learn a motor skill: performance *improvement* over a period of time, an increase in trial-to-trial performance *consistency,* an increase in performance *stability,*