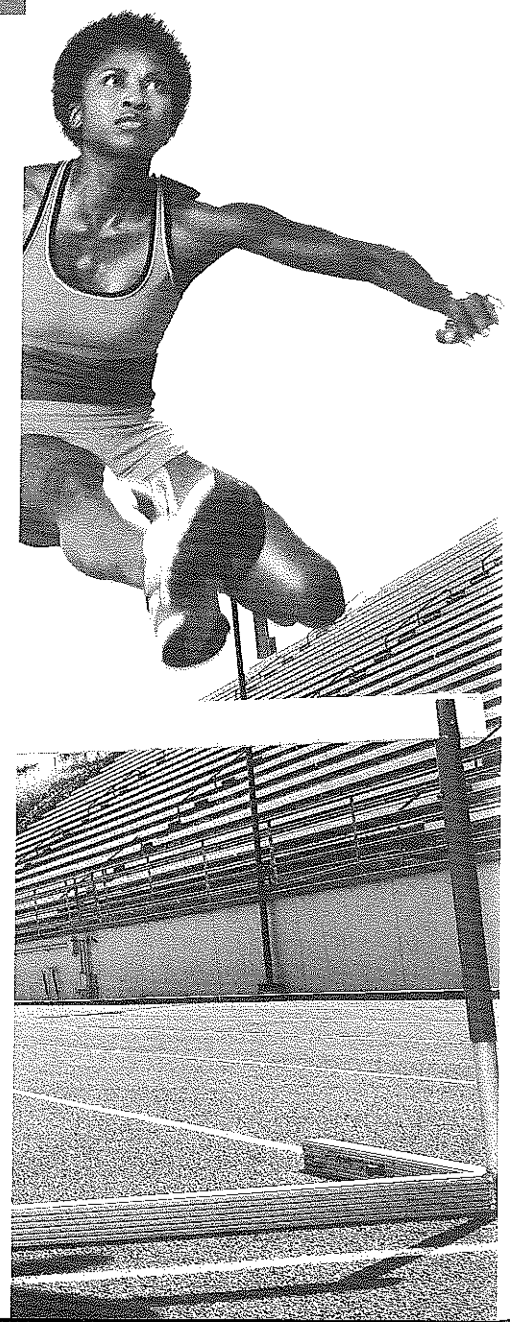
UNIT FIVE

Instruction and Augmented Feedback



CHAPTER 14

Demonstration and Verbal Instructions

Concept: Effective methods of providing instructions for helping a person to learn motor skills depend on the skills and the instructional goals.

After completing this chapter, you will be able to

- Describe what an observer perceives from a skilled demonstration of a motor skill and procedures researchers have used to arrive at this conclusion
- Discuss the influence of beginners observing other beginners as they practice a skill
- Identify the main features of the two predominant theories about how observing a demonstration helps a person learn a motor skill
- Give examples of how instructions can influence where a person directs his or her attention when performing a motor skill
- Define *verbal cues* and give examples of how they can be used in skill learning or relearning situations

APPLICATION

If you wanted to instruct someone about how to perform a skill, how would you do it? Probably, you would demonstrate the skill, verbally describe what to do, or use some combination of both approaches. But do you know enough about the effectiveness of these different means of communication to know which one to prefer or when to use each one or both?

Demonstrating skills is undoubtedly the most common means of communicating how to perform them. We find demonstrations in a wide range of skill acquisition situations. For example, a physical education teacher may demonstrate to a large class how to putt in golf. An aerobics teacher may demonstrate to a class how to perform a particular sequence of skills. A baseball coach may show a player the correct form for bunting a ball. In a rehabilitation context, an occupational therapist may demonstrate to a patient how to button a shirt, or a physical therapist may demonstrate to a wheelchair patient how to get from a bed into the chair. Consider also some examples of how practitioners in other professions use demonstration as an instructional strategy. Aerobics and fitness instructors often demonstrate to their clients how to perform specific activities. Pilates and yoga instructors show their clients how to perform specific movements. And athletic trainers commonly demonstrate taping techniques to student trainers.

The practitioner demonstrates a skill because he or she believes that in this way the learner receives the most helpful, as well as the most amount of, information in the least amount of time. But, we should know when demonstration is effective and when it may be less effective than some other means of communicating how to perform a skill.

Similarly, the instructor should know when verbal instructions are an effective means of communicating

how to perform a skill. And if verbal instructions are given, what characterizes the most effective instructions?

Application Problem to Solve Describe a motor skill that you might help people learn. Describe how you would provide them with information about how to perform the skill before they begin practicing the skill. Indicate why you would present this information in this way and not in some other way.

DISCUSSION

It is ironic that although demonstration is a very common method of providing information about how to perform a skill, there is not as much research related to it as we might expect. However, in recent years researchers have shown an increased interest in the role of demonstration in motor skill learning.

There seem to be at least two reasons for the increased interest in demonstration and skill learning. One reason is the phenomenal growth of interest in the role of vision in skill learning. Because demonstrating how to do a skill typically involves visual observation on the part of the learner, researchers have been able to use the study of demonstration and skill learning to assess how the visual system is involved in skill acquisition and performance. Another reason for the current interest is that we know so little about how to effectively implement this very common instructional strategy. As a result, researchers have been making an increased effort to improve our understanding of the role of demonstration in skill instruction and learning.

DEMONSTRATION

The terms **modeling** and **observational learning** often are used interchangeably with the term *demonstration*. Because *demonstration* is more specific to the context of instruction about how to perform a skill, we will use this term in this text.

In a comprehensive review of research investigating the role of demonstration in motor skill acquisition, McCullagh and Weiss (2001) discussed evidence that indicates demonstration is more effective under certain circumstances than under others. And in an article that reviewed research concerning instruction of sports skills, Williams and Hodges (2005) questioned many popular beliefs that influenced practice and instruction in the coaching of soccer. One of the beliefs they questioned, which the researchers listed as "myths," was "Myth 1: Demonstrations are always effective in conveying information to the learner" (p. 640). Thus both reviews of research related to the effectiveness of demonstrations as an instructional strategy concluded that the practitioner should use demonstration only after determining that the instructional situation indeed warrants the use of demonstration, rather than some other form of providing information about skill performance. In the following sections, we consider some of the concerns that practitioners need to take into account before making this instructional decision.

What the Observer Perceives from a Demonstration

The decision about the situations in which demonstration would be preferred should be based on our knowledge of what a person actually "sees" when a skill is demonstrated. Note the use of the word "sees" rather than "looks at." What we see and what we look at can be very different. What we "see" is what we *perceive* from what we look at. This distinction is particularly relevant to the discussion of demonstration, because what a person perceives from a skill demonstration is not necessarily something that he or she specifically

modeling the use of demonstration as a means of conveying information about how to perform a skill.

observational learning learning a skill by observing a person perform the skill; also known as *modeling.*

A CLOSER LOOK

Perceiving a Throwing Action from Observing a Point-Light Display

An experiment by Williams (1988) provides an example of the use of the point-light technique. Eighty adults (ages eighteen to twenty-five years) and eighty children (ages fourteen to fifteen years) observed a video point-light display of a side view of the arm of a seated person throwing a small plastic ball at a target (see figure 14.1). The video showed only dots of light at the shoulder, elbow, and wrist joints of the person throwing the ball. The author showed participants the video three times and then asked them what they had seen. Results showed that 66 percent of the children and 65 percent of the adults responded that they had seen a throwing motion. An additional 25 percent of the adults and 23 percent of the children made this response after seeing the video one additional time.

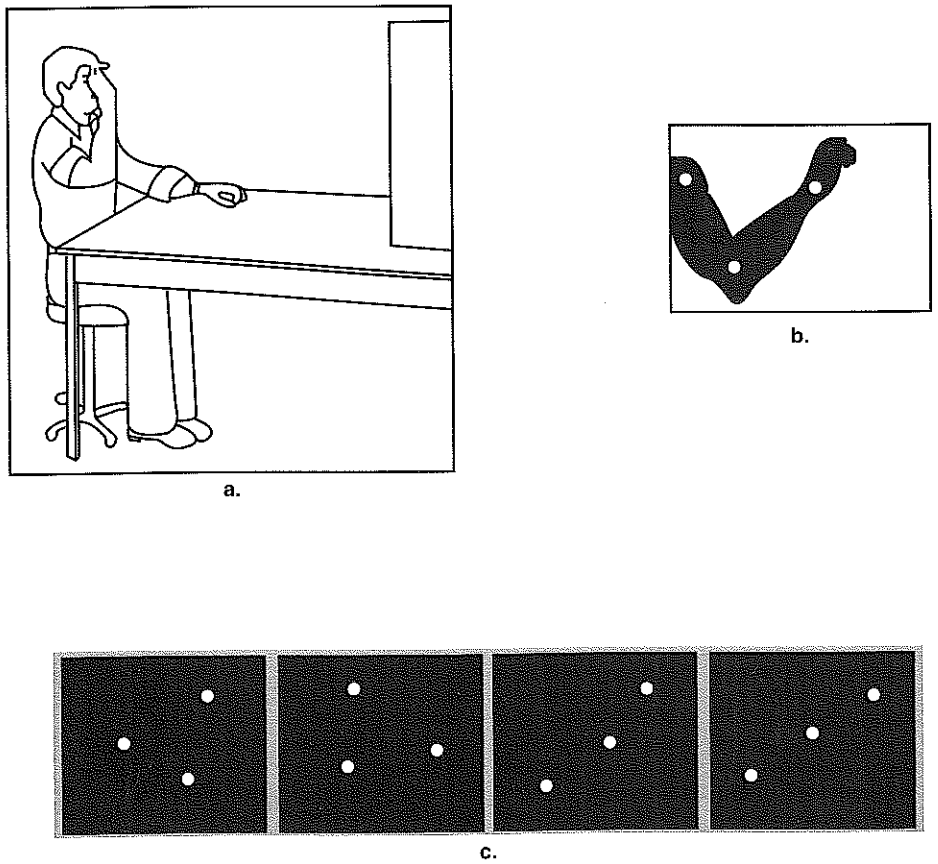


FIGURE 14.1 An example of use of the point-light technique in motor learning research. (a) The model demonstrating the throwing of a small ball at a target. (b) A static image of the point-light display of the model's arm with lights at the shoulder, elbow, and wrist joints. (c) Four still frames of the video shown to subjects. From left to right, these depict the arm at the start of the throw, at maximal flexion, at release of the small ball, and at completion of the throw. [Reproduced with permission of author and publisher from Williams, J. G. (1989). Visual demonstration and movement production: Effects of timing variations in a model's action. *Perceptual and Motor Skills, 68,* 891–896. © Perceptual and Motor Skills 1989.]

looks at or looks for. It is also important to keep in mind that what we perceive may be at a conscious or nonconscious level of awareness. For example, when people are asked later to describe verbally what they saw in a demonstration that helped them perform a skill, they do not always give a very accurate accounting.

Research evidence has shown consistently that the observer perceives from the demonstration information about the coordination pattern of the skill (e.g., Ashford, Bennett, & Davids, 2006; Horn & Williams, 2004). More specifically, *the observer perceives and uses invariant features of the coordinated movement pattern* to develop his or her own movement pattern to perform the skill.

Two types of research evidence support this view. One involves the investigation of the visual perception of motion; the other is the investigation of the influence of demonstration on learning a complex skill. Taken together, these two types of research indicate that the visual system automatically detects in a movement pattern invariant information for determining how to produce the observed action. In some manner, which scientists do not fully understand and continue to debate, the person translates the perceived information into movement commands to produce the action.

The Visual Perception of Motion

Research investigating the perception of human motion attempts to answer questions about how people recognize movement patterns they see in their world. An important principle developed from this research is that people rarely use specific characteristics of the individual components of a pattern to make judgments about the pattern. Rather, they use relative information about the relationships among the various components.

Using a procedure known as the **point-light technique,** researchers have identified the relative information involved in the visual perception of human movement. This procedure involves placing lights or light-reflecting markers on the joints of a person who is then filmed or videotaped performing an action or skill. Then the researcher plays the film or video so that the person who watches the film or video sees only bright dots in motion. The first reported use of this procedure (Johansson, 1973) showed that people could accurately label different gait patterns, such as walking and running, by observing the moving dot patterns. Later, Cutting and Kozlowski (1977) showed that from observing moving dot patterns, people actually could identify their friends. Since that time, an impressive amount of research has shown similar results for the perception of human motion based on point-light displays of a variety of movements. (For a review of this research see Blake & Shiffar, 2007). Using a computer simulation, Hoenkamp (1978) showed that the movement characteristic people use to identify different gait patterns is not any one kinematic variable, but the *ratio of the time duration between the forward and return swings of the lower leg.*

This groundbreaking research on the perception of human movement provided two important conclusions that help our understanding of observational learning. First, people can recognize different gait patterns accurately and quickly without seeing the entire body or all the limbs move. Second, the most critical information people perceive in order to distinguish one type of gait pattern from another is not any one characteristic of the gait, such as velocity of the limbs. Instead, people use the invariant relative time relationship between two components of gait. From these conclusions we can hypothesize that the invariant relationships in coordinated movement constitute the critical information involved in observational learning.

point-light technique a research procedure used to determine the relative information people use to perceive and identify coordinated human actions; it involves placing LEDs or light-reflecting material on certain joints of a person, then filming or videotaping the person performing an action; when an observer views the film or video, he or she sees only the points of light of the LEDs or light-reflecting markers, which identify the joints in action.

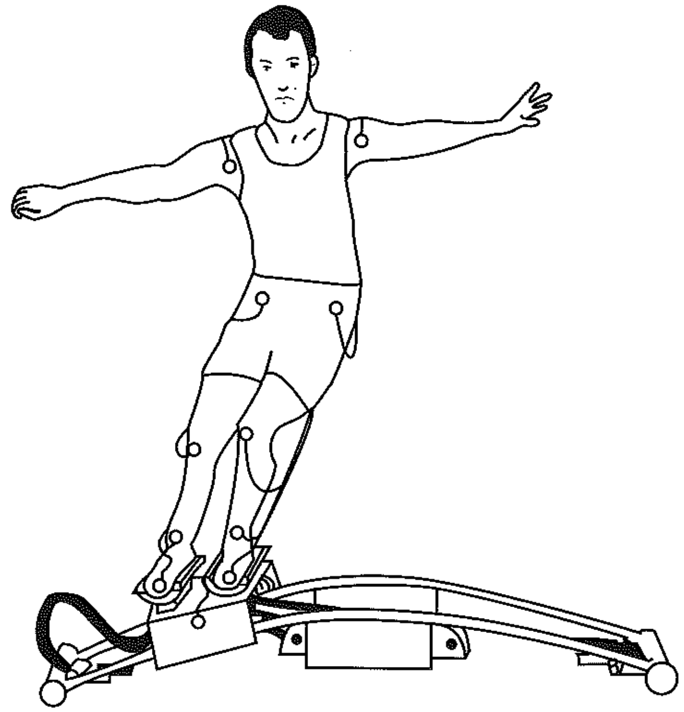


FIGURE 14.2 A person performing on the slalom ski simulator. Note that the person has attached LED markers for movement analysis purposes.

Investigating What the Observer Perceives from a Skilled Demonstration

The second type of research providing evidence about what an observer uses from a skill demonstration provides more direct evidence that people perceive invariant relationships. An example is an experiment by Schoenfelder-Zohdi (1992) in which subjects practiced the slalom ski simulator task shown in figure 14.2. This simulator consisted of two rigid, convex, parallel tracks on which a movable platform stood. A participant stood on the platform with both feet and was required to move the platform to the right and then to the left as far as possible (55 cm to either side) with rhythmic slalom ski–like movements. The platform was connected on either side to each end of the apparatus by strong, springlike rubber bands, which ensured that the platform always returned to the center (normal) position. Thus, the participant had to learn to control the platform movement by using smooth ski-like movements, just as he or she would if actually skiing. Participants practiced this skill for several days after they had either observed a skilled model perform the task or received verbal information about the goal of the task. A movement analysis of limb movements showed that participants who had observed the skilled demonstration developed coordinated movement patterns earlier in practice than did those who had not observed the demonstration. Figure 14.3 shows one example of these results.

Similarities between a skilled model's and a novice's coordination characteristics provide important evidence that observers of skilled demonstrations detect and use invariant coordination features to guide their own performance of a skill. However, stronger support of this conclusion comes from evidence showing performance similarities that result from observations of full-body and point-light models. An example of this type of evidence was provided by Horn, Scott, Williams, and Hodges (2005). They found that observers who watched video displays and those who watched point-light displays

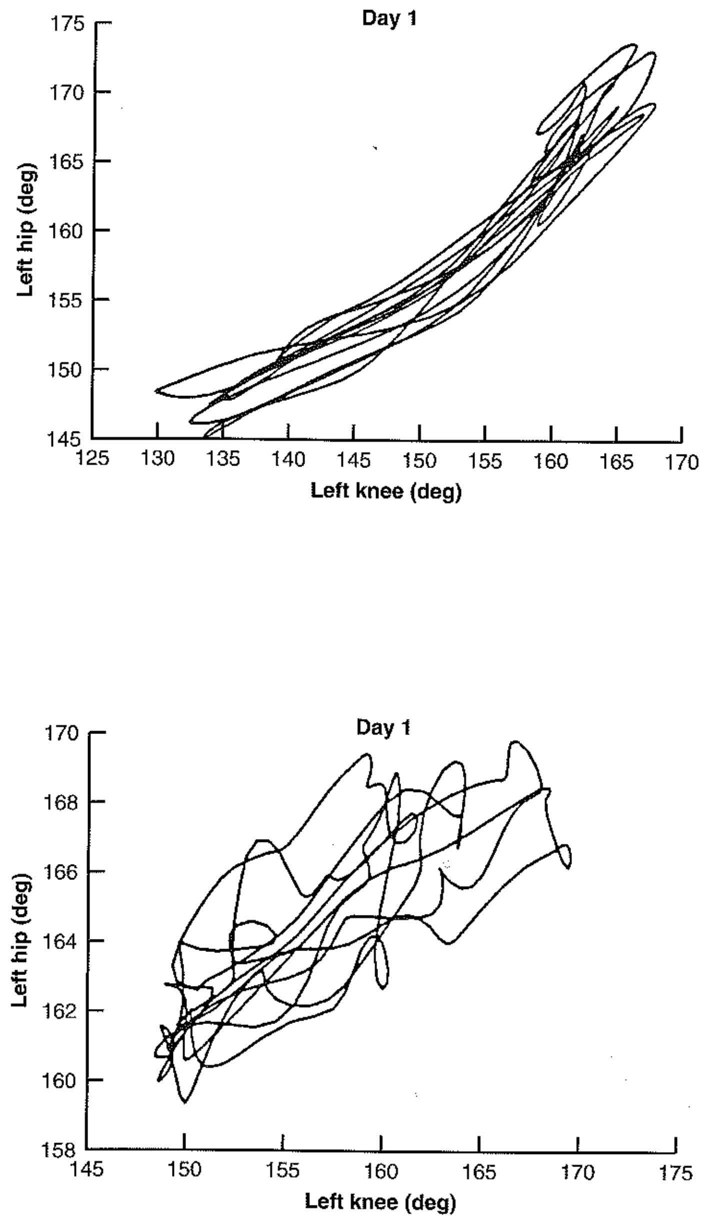


FIGURE 14.3 Angle-angle diagrams of the left knee and left hip for two people practicing on the slalom ski simulator. Both graphs show the relationship of these joints after one day of practice. The top graph is from the person who watched a skilled model demonstrate; the lower graph is from the person who did not watch a demonstration. [From Schoenfelder-Zohdi, B. G. (1992). *Investigating the informational nature of a modeled visual demonstration*, Ph. D. dissertation, Louisiana State University. Reprinted by permission.]

of a soccer-chipping skill showed no differences in their imitation of the model's relative motion characteristics. Additionally, a study by Abernethy and Zawi (2007) showed that expert badminton players predicted the direction of an opponent's strokes in advance of racquet–shuttlecock contact just as well when they viewed full-body film and point-light displays. Although this study did not investigate modeling, it demonstrates that, through years of observing opponents in action, skilled athletes

A CLOSER LOOK

Clinical Implications of a Mirror Neuron System

In a review of mirror neuron research, Pomeroy and colleagues in London, England (Pomeroy et al., 2005) concluded that the existence of a human mirror neuron system in the brain suggests the beneficial use of observation-based therapy for the rehabilitation of upper arm movement in poststroke patients. The therapy would involve stroke patients observing a healthy person's arm movements during goal-directed activities. Since that proposal, researchers have reported experiments that have found support for the benefit of observational learning (referred to as "action observation" by rehabilitation researchers) for improving arm and hand function of stroke patients, especially when combined with regular physical therapy (e.g., Celnik, Webster, Glasser, & Cohen, 2008; Ertelt, Small, Solodkin et al., 2007).

learned to visually detect and use invariant kinematic information related to specific movement coordination patterns. (For an in-depth review of research addressing the question of what is learned during observational learning, see Hodges, Williams, Hayes, & Breslin, 2007).

The Influence of Skill Characteristics

Research investigating the influence on learning of demonstration has produced equivocal findings about the effectiveness of skill demonstration. Some researchers have found that demonstration leads to better skill learning than other forms of instruction; others have found that it does not. But as Magill and Schoenfelder-Zohdi (1996) pointed out, a closer inspection of that research leads to the conclusion that the influence of demonstration on skill acquisition depends on characteristics of the skill being learned. The most important characteristic leading to the beneficial effect of demonstration is that the skill being learned requires the *acquisition of a new pattern of coordination.*

We see this clearly when we organize into two categories the results of research investigating the effect of demonstration on skill learning. In one category are those experiments in which participants learned more quickly after demonstration than after other forms of instruction. In experiments in this category, participants typically learned skills requiring them to acquire new patterns of limb coordination. In the other category are experiments in which participants usually learned skills no better after observing demonstrations than after receiving other forms of instruction. In these experiments, the participants practiced skills that required them to acquire new parameter characteristics for well-learned patterns of limb coordination.

THE NEURAL BASIS FOR OBSERVATIONAL LEARNING: MIRROR NEURONS IN THE BRAIN

In the early 1990s, neuroscientists in Italy, led by Giacomo Rizzolatti, discovered that when monkeys observed another monkey reach out its arm to grasp something, neurons in the F5 area of their premotor cortex became active (see Rizzolatti & Craighero, 2004; Miller, 2005). These neurons, known as *mirror neurons*, are a specific class of visuomotor neurons in the brain. The important question for understanding the neural basis for observation learning by humans is this: Does the human brain contain mirror neurons? Several studies have provided evidence that supports mirrorlike neurons in the human brain.

In one study, a group of neuroscientists in Los Angeles, California, pooled data from seven fMRI studies in which people observed and imitated simple finger movements (Molnar-Szakacs, Iacoboni, Koski, & Mazziotta, 2005). The researchers noted that during observation, specific areas activated in the *inferior frontal gyrus (IFG),* which is in the inferior frontal lobe of the cerebral cortex. Two sections of the IFG activated during observation

A CLOSER LOOK

Beginners Learn by Observing Other Beginners: Learning the Tennis Volley

An experiment by Hebert and Landin (1994) nicely illustrates how practitioners can facilitate skill acquisition for beginners by having them observe other beginners.

Participants: Female university students who had no previous formal training or regular participation in tennis

Task: Tennis forehand volley with the nondominant hand

Practice procedures: All participants first saw a brief instructional videotape that emphasized the basic elements of the volley

- *Learning model group:* Participants practiced the volley for fifty trials; the instructor provided verbal feedback after each trial. Each student in this group had a student, who was not in this group, observe and listen to a videotape of her practice trials.
- *Observer groups:* After observing the learning models, participants were divided into two groups and began their own fifty trials of practice.
  —*Observer group with verbal feedback:* Participants in this group received verbal feedback from the instructor after each practice trial.
  —*Observer group without verbal feedback:* Participants in this group did not receive verbal feedback from the instructor after each practice trial.
- *Control group:* Participants in this group practiced fifty trials of the volley without having observed the learning model participants or receiving verbal feedback from the instructor.

Results: On a posttest of the volley given after the practice trials, both observer groups performed better than the control group.

Conclusion: Having beginning tennis players observe other beginners practice a skill before they begin to practice will facilitate their learning of the skill.

(the pars triangularis and the dorsal section of the pars opercularis) but not during the movement imitation. Interestingly, the IFG includes the region of the brain known as Broca's area, which is important in speech production.

Researchers in Germany (Zentgraf et al., 2005) used fMRI to assess brain activity during the observation of whole-body gymnastics movements. Their results showed that when participants were asked to observe with the intent to imagine themselves imitating the movements, activation was recorded in the *supplementary motor area (SMA)* of the cortex. Interestingly, when the participants were asked to observe the movements with the intent to judge their accuracy and consistency, the pre-SMA area activated. Other fMRI research has found mirrorlike neuron activity in the *parietal cortex,* which is involved in interhemispheric visuomotor integration (Iacoboni & Zaidel, 2004), and *lateral temporal cortex,* which is involved in processing complex visual motion (Beauchamp, Lee, Haxby, & Martin, 2003). In addition to using fMRI, researchers have also used EEG recordings to provide evidence of the involvement of a mirror neuron system during action observation (e.g., Calmels, Hars, Holmes, Jarry, & Stam, 2008).

Taken together, these brain activity recording methods indicate the existence of a mirror neuron system, although many questions remain unresolved concerning its specific characteristics and functions. (For a more complete review of research on the mirror neuron system and its implications for physical rehabilitation, see Iacoboni & Mazziotta, 2007).

Observing Skilled Demonstrations

A common guiding principle for demonstrating a skill is that the demonstrator should perform the skill correctly. Why would more accurate demonstration lead to better learning? Two reasons are evident from the research literature. The first reason follows our discussion of perception of information in the preceding section. If the observer perceives and uses information related to invariant movement patterns, it is logical to expect the quality of performance resulting from observing a demonstration to be related to the quality of the demonstration. Another reason is that in addition to picking up coordination information, an observer also perceives information about the strategy used by the model to solve the movement problem. Typically, the observer then tries to imitate that strategy on his or her initial attempts at performing the skill.

Novices Observing Other Novices Practice

Although the theoretical predictions and the empirical evidence indicate that it is preferable for beginners to observe skilled demonstrators, evidence indicates that beginners can derive learning benefits even from observing unskilled demonstrators, especially if both the observers and the models are beginners. What this means is that the models are "demonstrators" only in that the observers are watching them practice.

One proposed benefit of this use of demonstration is that it discourages imitation of a skilled model's performance of the skill and encourages the observer to engage in more active problem solving. We can trace evidence for the benefit of this approach to the 1930s (e.g., Twitmeyer, 1931), although widespread interest in this approach did not develop until Adams (1986) published some experiments. Since then, others have pursued the investigation of the use and benefit of observing an unskilled model (e.g., McCullagh & Meyer, 1997; Pollock & Lee, 1992; Weir & Leavitt, 1990). Results of this research have consistently shown that beginners who observe other beginners practicing a skill will perform at a higher level when they begin to perform than the beginners they observed.

One way to effectively implement this use of demonstration is by pairing students, athletes, or patients in situations where one of the pair performs the skill while the other observes. After a certain number of trials or amount of time, the pair switches roles. On the basis of what we know

LAB LINKS

Lab 14 in the Online Learning Center Lab Manual provides an opportunity for you to experience how a beginning learner observing another beginner practice can facilitate the learning of the observer when he or she begins to practice the skill.

from the research literature, learning of the skill can be facilitated for both the performer and the observer by having the teacher, coach, therapist, or some other knowledgeable person provide verbal feedback to the performer. Another effective strategy is to provide the observer of the pair with a checklist of key aspects of the skill. The observer should look for each aspect, check it on the list, and then provide some feedback to the performer. Under these conditions, the observer actively engages in problem-solving activity that is beneficial for learning. The learner observes what the unskilled model does, what the "expert" tells him or her is wrong with the attempt, what the model does to correct errors, and how successful he or she is on the succeeding attempts.

The Timing and Frequency of Demonstrating a Skill

One of the reasons for demonstrating a skill is to communicate how to perform the skill. For the beginner, demonstration provides an effective means of communicating the general movement pattern of the action or skill. As we discussed in chapter 12, Gentile considered this to be the goal of the first stage of learning. When applied to the use of demonstration, Gentile's view suggests two things. The first is that it is beneficial to demonstrate a skill *before the person begins practicing it.* The second is that the instructor should *continue demonstrating during practice as frequently as necessary.*

Earlier, we pointed out that a skilled demonstration communicates the invariant characteristics of a movement pattern. If this is the case, then we would expect that the more frequently a beginner observes a skilled demonstration, the more opportunity the beginner will have to acquire the movement pattern.

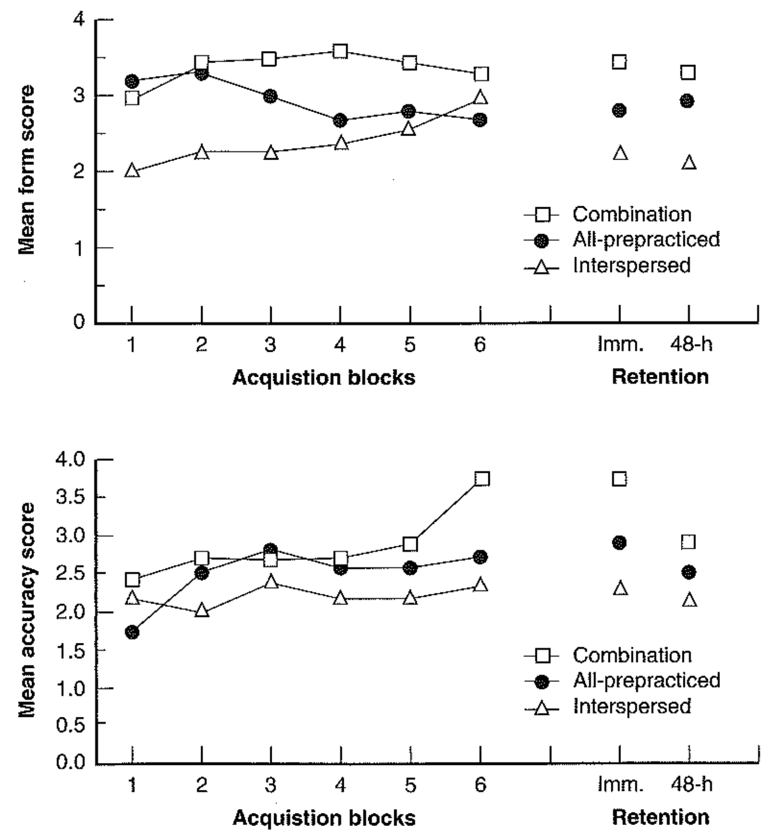


FIGURE 14.4 The results of the experiment by Weeks and Anderson showing form and accuracy scores for practice trials and retention tests for an overhand volleyball serve for three groups that observed ten skilled demonstrations in different amounts and at different times before and during practice. The form scores represent the mean of ten aspects of form, each rated on a scale of 0 to 5, with 0 indicating a complete absence of the aspect, and 5 indicating the aspect was performed as recommended. [Source: Figures 1 (p. 266) and 2 (p. 267) in Weeks, D. L., & Anderson, L. P. (2002). The interaction of observational learning with overt practice: Effects on motor learning. *Acta Psychologica, 104,* 259–271.]

At least two research studies support this latter point. One, by Carroll and Bandura (1990), involves the learning of complex movement patterns of a computer joystick; the other, by Hand and Sidaway (1993), involves the learning of a golf skill. Both experiments provided evidence that more frequent observations of the model yielded better skill learning.

An experiment by Weeks and Anderson (2000), which investigated the issue of the timing of demonstrations, provides some additional insight into both the timing and frequency questions. The demonstrated skill involved a skilled volleyball player hitting an overhand serve. Participants, who had no previous experience hitting this serve, observed a video of ten demonstrations and performed thirty serves. The all-prepractice group watched all ten before performing the thirty serves; the interspersed group observed one demonstration and then performed three serves, in series throughout the practice period, and the combination group viewed five demonstrations before performing fifteen serves, then viewed five demonstrations before performing the final fifteen serves. All participants performed in two retention tests, which were 5 min and 48 hr respectively after the practice session. The results (figure 14.4) showed the benefit of the combination and all-prepractice conditions, as both led to better form and accuracy scores than the interspersed condition. In terms of the timing and frequency of demonstrations, these results indicate that several demonstrations should precede practice. Although it would be interesting to see how these demonstration schedules would have influenced learning had they been implemented in several days of practice, the results for one practice session reveal the importance of prepractice demonstrations.

Auditory Modeling

Our discussion so far has focused on visual demonstration. However, there are skills for which visual demonstration is less effective for learning than other forms of demonstration. An example is a skill for which the *goal is to move in a certain criterion movement time or rhythm*. For these types of skill, an auditory form of demonstration seems to work best.

A good research example of the effectiveness of auditory modeling when the goal is a specific movement time is an experiment by Doody, Bird, and Ross (1985). The task required people to perform a complex sequential movement with one hand in a criterion movement time of 2.1 sec. Visual and auditory demonstration groups observed a videotape of a skilled model before each practice trial. The visual demonstration group saw only the video portion of the tape and heard no sound. The auditory demonstration group heard only the audio portion of the modeled performance and did not see the task performed by the model. Results indicated that the group that heard the audio portion of the performance did better than the visual demonstration–only group.

Two research examples of the benefit of auditory modeling to aid the learning of a rhythmic sequence involve a laboratory task and a sequence of dance steps. In an experiment by Wuyts and Buekers (1995), people who had no prior dance or music experience learned a sequence of thirty-two choreographed steps. For acquiring the rhythmic timing of this sequence, participants who heard only the timing structure learned it as well as those who both saw and heard the sequence performed by a model. The second example is an experiment by Lai, Shea, Bruechert, and Little (2002) in which they found that auditory modeling enhanced the learning of a sequence of five time intervals when two keyboard keys were alternately depressed. Before each practice trial, participants heard a sequence of tones that represented the timing sequence they were to learn.

How the Observing of Demonstrations Influences Learning

In terms of learning theory, an important question is this: Why does observing demonstrations benefit motor skill learning? Two different views propose answers to this question.

Cognitive mediation theory. The predominant view is based on the work of Bandura (1986) concerning modeling and social learning. This view, called the **cognitive mediation theory,** proposes that when a person observes a model, he or she translates the observed movement information into a symbolic memory code that forms the basis of a stored representation in memory. The reason the person transforms movement information into a cognitive memory representation is so that the brain can then rehearse and organize the information. The memory representation then serves as a guide for performing the skill and as a standard for error detection and correction. To perform the skill, the person first must access the memory representation and then must translate it back into the appropriate motor control code to produce the body and limb movements. Thus, cognitive processing serves as a mediator between the perception of the movement information and the performance of the skill by establishing a cognitive memory representation between the perception and the action.

According to Bandura, four subprocesses govern observational learning. The first is the *attention process,* which involves what the person observes and the information he or she extracts from the model's actions. Because of the importance of the attention process for learning, directing full attention to the demonstration rather than the mere observation of it is important for optimal learning. The second is the *retention process,* in which the person transforms and restructures what he or she observes into symbolic codes that the person stores in memory. Certain cognitive activities, such as rehearsal, labeling, and organization are involved in the retention process and benefit the development of this representation. The *behavior reproduction process* is the third subprocess; during it, the person translates the memory representation of the modeled action and turns it into physical action. Successful accomplishment of this process requires that the individual possess the physical capability to perform the modeled action. Finally, the *motivation process* involves the incentive or motivation to perform the modeled action. This process, then, focuses on all those factors that influence a person's motivation to perform. Unless this process is completed, the person will not perform the action.

Several research studies have provided support for the cognitive mediation theory by demonstrating evidence that is in line with predictions of the theory. For example, Ste.-Marie (2000) provided support for the prediction that *attention* is an important process in observational learning. In a series of four experiments, participants who had to divide their attention between performing a cognitive secondary task (counting backwards by threes) and observing a model did not learn the skill as well as those who did not perform a secondary task. In an experiment discussed in chapter 10, Smyth and Pendleton (1990) showed that the prevention of the *rehearsal* process hindered learning a skill. In their experiment, some participants engaged in movement activity during the interval of time between the demonstration of a sequence of movements and their attempts to reproduce those movements. These participants recalled fewer movements than those who did not engage in activity during this time interval. And Blandin and Proteau (2000) provided evidence that observational learning involves the development of effective *error detection and correction,* which the cognitive mediation theory describes as an important function of the memory representation that develops during observational learning. In two experiments, participants' estimations of their performance error and their use of that estimation on the next practice trials were similar for an observational learning situation and one in which participants did not observe a model.

Dynamic view of modeling. The second view is based on the direct perception view of vision proposed many years ago by J. J. Gibson (1966, 1979). Scully and Newell (1985) adapted Gibson's view to the visual observation of a skilled demonstration and proposed the **dynamic view of modeling** as an alternative to Bandura's theory. The dynamic view questions the need for a symbolic coding step (the memory representation step) between the observation of the modeled action and the physical performance of that action. Instead, it maintains, the visual system is capable of automatically processing visual information in such a way that it constrains the motor control system to act according to what the vision detects. The visual system "picks up" from the model salient information that effectively constrains the body and limbs to act in specific ways. The person does not need to transform the information received via the visual system into a cognitive code and store it in memory. This is the case because the visual information directly provides the basis for coordination and control of the various body parts required to produce the action. Thus, the critical need for the observer in the early stage of learning is to observe demonstrations that enable him or her to perceive the important invariant coordination relationships between body parts. Additional observations of the model will benefit the learner by helping the person learn to parameterize the action.

In addition to the type of research evidence provided in the experiment by Schoenfelder-Zohdi (1992), which we considered earlier, evidence based on the use of the point-light display as the model has supported the prediction that the observer of a skilled demonstration perceives invariant coordination characteristics. An experiment by Horn, Williams, and Scott (2002) is a good example of this type of evidence. Female novice soccer players viewed a video of a skilled performer, a point-light display of a skilled performer, or no model. The skill involved chipping a soccer ball a distance of 5 m over a barrier (0.35 m height) onto a target area located 2.5 m from the barrier. The point-light

cognitive mediation theory a theory for explaining the benefit of a demonstration proposing that when a person observes a skilled model, the person translates the observed movement information into a cognitive code that the person stores in memory and uses when the observer performs the skill.

dynamic view of modeling a theoretical view explaining the benefit of observing a skilled model demonstrate a skill; it proposes that the visual system is capable of automatically processing the observed movement in a way that constrains the motor control system to act accordingly, so that the person does not need to engage in cognitive mediation.

display, which was made from the video of the model performing the skill, showed eighteen light-reflecting markers attached to the models major joints. The video and point-light display were shown life-size to the participants on a screen at three different times during the practice session. The results showed that during practice and on a retention test, target accuracy was similar for the video and point-light display groups, with both groups more accurate than the no-model group. And the kinematic characteristics were similar for participants in the video and point-light display groups. As a result, the evidence provides support for the dynamic view's contention that the observer detects and uses coordination information based on the movement of limb segments, which is the only information the point-light display provided.

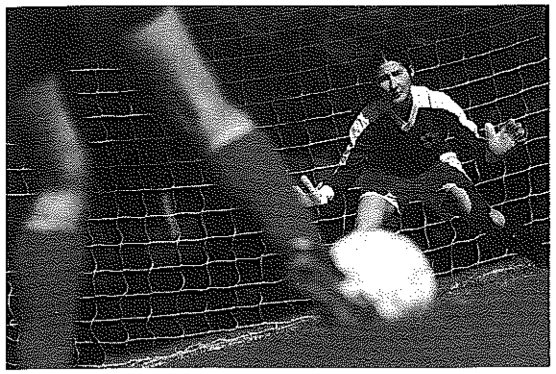
Which view is correct? Unfortunately, there is no conclusive evidence in the research literature that shows one of these two views of the modeling effect to be the more valid one. As you saw in the discussions of each view, both have research support for some specific assertions. As a result, until we have research evidence that one view cannot explain, we must consider which view is a possible explanation of why modeling benefits skill acquisition. The cognitive mediation theory has been the more prominent of the two, receiving more attention in motor skills research. However, the dynamic view is growing in popularity.

VERBAL INSTRUCTIONS AND CUES

Verbal instructions rank with demonstration as a commonly used means of communicating to people how to perform motor skills. Evidence supports the value of verbal instructions for facilitating skill acquisition. Several factors are particularly important for developing effective verbal instruction.

Verbal Instructions and Attention

An important performer characteristic we discussed in chapter 9 that relates to giving verbal instructions is that the person has a limited capacity to attend to information. Because of this limitation,



To teach goalkeeping skills, the instructor must decide when to use demonstrations and when to provide verbal instructions.

the practitioner must take into account several characteristics about the instructions they give. We will consider some of these in the following sections.

The quantity of instructions. It is easy to overwhelm the person with instructions about what to do to perform a skill. We can reasonably expect that a beginner will have difficulty paying attention to more than one or two instructions about what to do. Because the beginner will need to divide attention between remembering the instructions and actually performing the skill, a minimal amount of verbal information can exceed the person's attention-capacity limits. In addition to concerns about attention capacity, the instructor should include other important attention-related considerations when giving verbal instructions. Several of these are discussed in the following sections.

Verbal instructions to focus attention on movement outcomes. An important function of instructions is to direct learners' attention to focus on the features of the skill or environmental context that will enhance their performance of the skill. A key point with regard to the content of these instructions relates to our discussion of attention and consciousness in chapter 9. Recall that attention can be either conscious or nonconscious, with the person either aware or not aware of what is being attended to. When we relate this point to attention

focus during the performance of a motor skill, we need to review the research evidence we briefly discussed in chapter 9, which showed that a key part of skill learning is *where* a person directs his or her conscious attention when performing a skill. That research evidence was based on investigations of the *action effect hypothesis* (Prinz, 1997), which proposes that actions are best planned and controlled by their intended effects. The hypothesis predicts that actions will be more effective when a person focuses his or her attention on the intended outcomes of an action, rather than on the movements required by the skill. To test the action effect hypothesis in motor skill learning situations, researchers have designed experiments in which instructions that direct participants' attention to their own movements (i.e., internal focus of attention) are compared to those that direct attention to the movement outcome (i.e., external focus of attention) (see Wulf & Prinz, 2001, for a review of this research).

The following research examples illustrate two types of experiments that have tested and supported the action effect hypothesis. And they demonstrate *two different ways to give verbal instructions to direct attention to movement outcomes.* The first involves instructions presented in a way that establishes a *discovery learning* situation. This means that the instructions focus the learner's attention on the action goal of the skill. Then, as the learner practices the skill, he or she "discovers" how to move to achieve that goal. The second example involves the *use of metaphoric imagery* in instructions, which directs the learner's attention to move according to the image, which is the intended movement outcome of the skill. Recall that we discussed the use of metaphoric images in chapter 10 as a strategy for enhancing memory.

In a study reported by Wulf and Weigelt (1997) participants practiced the slalom-ski simulator task (described earlier in this chapter and pictured in figure 14.2). Everyone was told that the goal of the task was to continuously move the platform for 90 sec as far as possible to the left and right at a rate of one complete cycle every 2 sec. Participants in one group were also told to try to exert force on the platform after it passed the center of the ski simulator, based on a movement characteristic of people who demonstrated high performance levels on the ski simulator. Another group was not given this additional instruction, which means the only instructions they received concerned the action goal (i.e., the desired effect of their movements). Because they were told only about the action goal, this group experienced a discovery learning situation.

As figure 14.5 shows, the additional movement attention-directing instructions led to poorer performance during practice trials and on a transfer test in which participants performed under stress (they were told they were being observed and evaluated by a skiing expert). Interestingly, in a follow-up experiment, which was based on the assumption that more experience with the task would allow participants to direct more attention to the specific information in the instructions, the attention-directing instructions were given after three days of practice. But, once again, rather than aid learning, the instructions had a negative effect.

Numerous other research investigations have found that instructions that promote an external focus of attention lead to better learning than an internal focus. These studies are especially noteworthy because they have found this benefit for a variety of motor skills, such as swinging a golf club, shooting a basketball, serving a volleyball, passing in soccer, and throwing a dart. In addition, instructions to focus attention externally have been shown to benefit the learning of balance skills by healthy adults as well as those who have Parkinson's disease or who have had a stroke. (For brief reviews of the research showing these results, see Emanuel, Jarus, & Bart, 2008; Wulf, Landers, Lewthwaite, & Töllner, 2009; Wulf & Su, 2007).

An experiment in which instructions used *metaphoric imagery* to direct attention to the movement outcome was reported by Wulf, Lauterbach, and Toole (1999). Participants, who were university students with no previous experience playing golf, practiced hitting golf pitch shots into a circular target from a distance of 15 m. Everyone was given the same demonstration and instructions about the

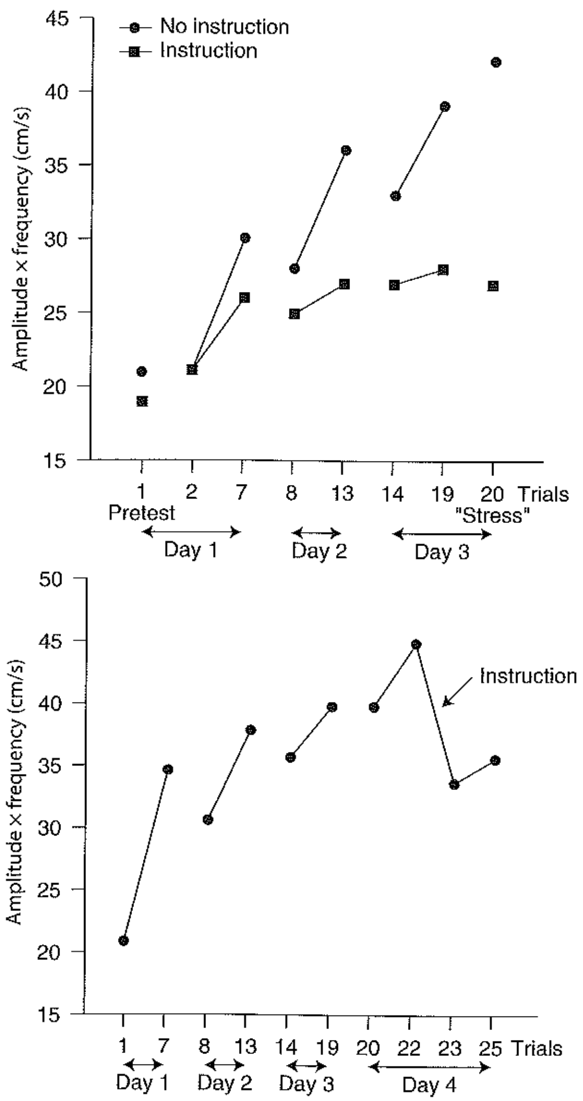


FIGURE 14.5 The top graph shows the results of the first experiment by Wulf and Weigelt which compared a group that received instructions about a movement component of the slalom ski simulator task and a group that did not receive the instructions. The bottom graph shows the results of their second experiment in which one group received the movement component instructions on the fourth day of practice. [Reprinted with permission from *Research Quarterly for Exercise and Sport, Vol. 1, No. 4,* 262–367. Copyright © 1997 by the American Alliance for Health, Physical Education, Recreation and Dance, 1900 Association Drive, Reston, VA 20191.]

stance and how to grip the club. But one group was told to focus their attention on the swinging motion of the arms during each swing. These participants also received specific instructions about the various movements involved in the swing and practiced several swings without holding a club before they practiced hitting a ball. A second group was told to focus their attention on the club head's pathway during the back- and down-swing (i.e., the "action effect"). They received specific instructions that emphasized the metaphor of the pendulum-like motion of the club. The results showed that the participants who directed their attention to the club movement consistently produced higher target accuracy scores during practice trials and on a 24 hr retention test.

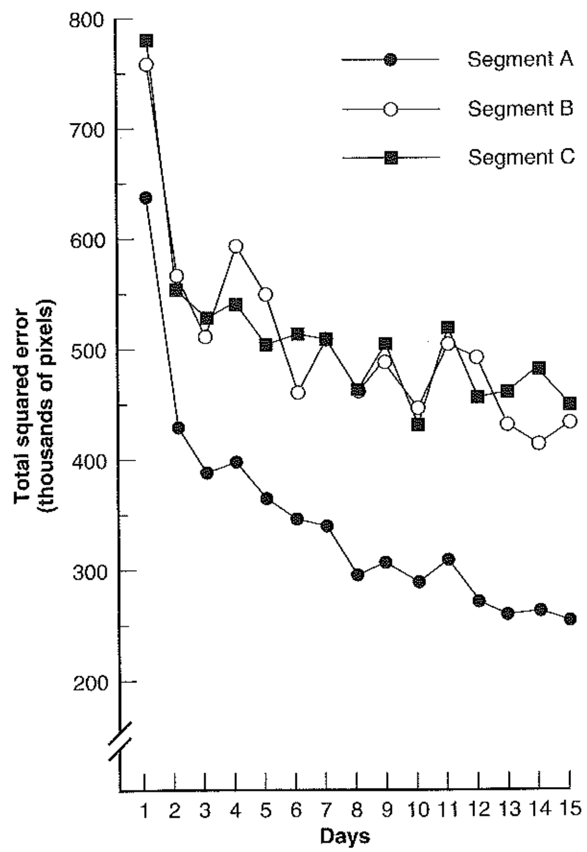


FIGURE 14.6 The results of the experiment by Magill, Schoenfelder-Zohdi, and Hall (1990) showing the superior performance on the repeated segment A compared to the random segments B and C for a complex tracking task. [Source: R. A. Magill et al., "Further Evidence for Implicit Learning in a Complex Tracking Task" paper presented at the annual meeting of the Psychonomics Society, November, 1990, New Orleans, LA.]

Verbal instructions to focus attention on invariant environmental context regulatory conditions. Another issue associated with attention and the content of instructions relates to the selective attention problem of what in the environment to look for that will help perform a skill. The importance of this issue relates to a critical goal of the initial stage of learning, accordingly to Gentile's learning stages model. As we discussed in chapter 12, this goal is to learn the regulatory conditions that direct the movements required to achieve the action goal of the skill.

Sometimes we ask people to tell us what they were looking for or looking at when they performed a skill, so that we can help them correct their visual attention focus. However, research investigating the need for conscious awareness of environmental cues when learning skills reveals that people can learn to select relevant cues from the environment without being consciously aware of what those cues are.

A good example of research demonstrating this result is an experiment reported by Magill (1998). Participants watched a target cursor move in a complex waveform pattern across a computer screen for 60 sec. The participants' task involved pursuit tracking of the target cursor by moving a lever on a tabletop to make their own cursor stay as close as possible to the target cursor. The unique feature was that the target cursor moved randomly for the second and third 20 sec segments on every trial, but it made the same movements on every trial during the first 20 sec segment. The participants practiced this pursuit-tracking task for approximately twenty-four trials on each of fifteen days. The results, shown in figure 14.6, indicated that as they practiced,

A CLOSER LOOK

Training Anticipatory Skills in Tennis with an Implicit Instructional Strategy

An objective of tennis instruction is to enhance players' capabilities to anticipate as early as possible the direction of a ball hit by an opponent. This objective was at the heart of an experiment by Farrow and Abernethy (2002) in which they compared two training techniques designed to increase junior tennis players' anticipation skills for returning serves. Both techniques were based on the hypothesis that the sources of information used by the skilled players to anticipate serve direction could be used to train less skilled players. All participants experienced the following sequence of tests and training: *Pretest—Training (4 wks, 3 days/wk)—Posttest—Retention Test (32 days later)*

Tests and Training

Participants watched videotapes of skilled players' serves, which were from the receiver's view. During the tests, their task was to indicate as quickly as possible whether the serve direction was to their forehand or backhand. On some trials they verbally indicated the direction, while on others they moved with their racquets in the direction. Tapes were edited and programmed to stop at one of five time periods before and after racquetball contact (i.e., temporal occlusion): T1—900 msec before ball contact (start of ball toss); T2—600 msec before ball contact (ball toss almost at zenith); T3—300 msec before ball contact (racquet at top of backswing); T4—at ball contact; T5—after follow-through. Each training session consisted of watching temporally occluded videotapes of various professional tennis players hitting serves and then physically practicing the return of 50 serves.

Training Techniques

Explicit instruction: Participants received specific instruction about the relationship between information sources in the server's action and the direction of a serve. These sources were highlighted in instructional videos, verbal and written information, and verbal feedback provided during the physical practice trials.

Implicit instruction: Participants received no specific instruction about the relationship between information sources in the server's action and the direction of a serve. They were told that their task was to estimate the speed of each serve seen on the videotape.

Results

Explicit rule information: Before and after the four-week training period, participants were asked to write down all the rules, coaching tips, and strategies they thought were important for returning serves. After training, the explicit training group wrote an average of 2.5 rules, while the implicit training group wrote an average of 0.5 rules.

Serve direction prediction accuracy: Overall, both training groups improved from the pretest to the posttest. But seven of the eight participants in the implicit training group improved prediction accuracy *at ball contact,* compared to three of eight in the explicit group.

Conclusion

Although the prediction accuracy differences between the two training conditions were relatively minor, their similarity is important. That the implicit training led to test performance that was similar to that of explicit training indicates that the anticipatory information required to predict serve direction can be learned without being consciously aware of the specific sources for the information. However, it is important to note two important characteristics of the implicit training condition:

1. The participants directed attention to the server and the serve on each videotape, because they had to estimate the speed of the serve.
2. The training period involved a large number of trials of observing a variety of servers and serves that were temporally occluded at various times before and after each serve.

they performed better on the first segment than on the other two segments. But what is more important is that when interviewed, none of the participants indicated that they knew that the target cursor made the same pattern during the first segment on every trial. Thus the participants attended to and used the

regularity of the cursor movement during the first segment, even though they were not consciously aware of that characteristic. This lack of conscious awareness of the invariant movement pattern of the target cursor indicates that the participants *implicitly* learned the regulatory environmental context features that directed their movements as they tracked the target cursor.

Although the research just described indicates that people can learn to use relevant environmental context features without being instructed to look for them, there is a common assumption that we can facilitate skill learning by giving instructions that would make people aware of these features. For example, a tennis teacher may tell a student that a certain racquet-head angle at ball contact during a serve indicates a specific type of serve, which the student should try to look for to predict that type of serve. However, what is not so commonly known is that this type of instruction could actually hinder rather than facilitate learning, especially when the specific features looked for occur infrequently in a series of trials.

Green and Flowers (1991) reported an experiment that serves as a good example of the research evidence demonstrating this negative effect. Participants played a computer game in which they manipulated a joystick to move a paddle horizontally across the bottom of the monitor to try to catch a "ball," which was a dot of light, that moved for 2.5 sec from the top to the bottom of the screen. The ball moved according to one of eight pathways. On 75 percent of the trials, the ball made deviations from the normal pathway that predicted the specific final position of the ball. Thus, participants' detection of these pathway-deviations characteristics could help them increase their catching accuracy. One group of participants received explicit instructions about these characteristics and their probability of occurring; the other group did not. Participants practiced for five days for a total of 800 trials. The results showed that both groups improved. However, the explicit-instruction group made more errors than the group that had had no instruction. The authors concluded that the instructed participants directed so much of their attentional resources to trying to remember the rule and looking for its occurrence that their performance was disrupted, because they did not have sufficient attention to devote to the catching task itself.

Research has also shown the negative influence of explicit information on the implicit learning of an open motor skill by stroke patients. In an experiment by Boyd and Winstein (2004), patients who had experienced a basal ganglia stroke practiced a pursuit tracking task similar to the one described earlier in the Magill (1998) study, except that a trial was only 30 sec. One group of patients was told about the repeating portion of the pathway. Rather than helping the patients to perform the task better than those who were not given this information, the awareness of this task characteristic led to poorer learning.

Verbal Instructions Influence Goal Achievement Strategies: Speed-Accuracy Skill Instructions

Another factor that we need to consider is that verbal instructions direct the person's attention to certain performance goals of the skill. A good example of this is the way verbal instructions can bias the strategy a person uses to learn speed-accuracy skills which we discussed in chapter 7. An experiment by Blais (1991) illustrates this type of strategy bias. The task was a serial pursuit tracking task in which participants controlled a steering wheel to align a pointer as quickly and accurately as possible to target positions on a screen. Three groups of participants received verbal instructions that emphasized being accurate, being fast, or being both accurate and fast. The instruction emphasis was especially evident during the first of the five days of practice. On this day, the "speed instruction" group recorded the fastest movement times, whereas the "accuracy group" produced the most accurate performance. The group told to emphasize both speed and accuracy adopted a strategy that led to fast movement times—but at the expense of performance accuracy. And although the "accuracy instruction" group performed the most accurately, its participants did so in a manner that eventually gave them the fastest average overall response time, which included reaction time, movement time, and

A CLOSER LOOK

Considerations for Experts When Giving Verbal Instructions to Novices

We generally assume that beginners should be taught by people who are highly skilled in the activity to be learned. However, highly skilled performers (i.e., experts) can have problems when they give verbal instructions to beginners. We might expect certain types of problems because of some of the differences between experts and novices that we considered in chapter 12. Two differences that are especially relevant are these:

- *Their knowledge structures about the skill.* Compared to those of novices, experts' knowledge structures tend to be more conceptual and organized, with more interrelationship among the concepts. Novices, on the other hand, tend to have knowledge structures that involve more concrete and specific pieces of information, with few concepts and interrelationships among them.
- *The attention demands required to perform the skill.* Novices need to direct conscious attention to more, and different, aspects of the performance of a skill than experts.

An experiment by Hinds, Patterson, and Pfeffer (2001) provides some evidence and insight about the problems experts can have providing instructions to novices. In this experiment, experts in the domain of electronics instructed novices about how to build an electronic circuit, which involved connecting wires in specific ways to make the electronic components for several different devices, such as a radio or motion detector. Results showed that the experts provided instruction that was too conceptual and included too few concrete details to guide the novices. Interestingly, the experts' self-reported assessment of their teaching skill did not correlate well with the type of instructions they provided.

movement-correction time for errors. Thus, for this task, where both speed and accuracy were equally important for overall performance, instructions that initially emphasize accuracy led to the best achievement of the two-component goal.

The results of the Blais (1991) experiment are consistent with predictions of both the motor program and dynamic pattern theories we discussed in chapter 5. To apply the speed-accuracy skill to those theories, the movement accuracy component refers to the movement pattern used to perform the skill. In both theories the movement pattern consists of invariant characteristics that remain the same when the skill is performed at different speeds. For these motor control theories, movement speed can be readily changed according to the demands of the performance situation or intention of the performer. As a result, these theories predict that initial practice for a speed-accuracy skill should emphasize movement accuracy and a later emphasis on the speed component.

Verbal Cues

One of the potential problems associated with verbal instructions is that they can contain too little or too much information and not provide the learner with what he or she needs to know to achieve the goal of the skill. To overcome this problem, instructors can use verbal cues to direct people to know what to do to perform skills (Landin, 1994). **Verbal cues** are short, concise phrases that serve to (1) direct the performer's attention to regulatory conditions in the environmental context or (2) prompt key movement components of skills. For example, the cue "Look at the ball" directs visual attention, whereas the cue "Bend your knee" prompts an essential movement component. Research has shown these short, simple statements to be very effective as verbal instructions to facilitate learning new skills, as well as performing well-learned skills. Teachers, coaches, or therapists can implement verbal cues in several different ways in skill learning settings.

Verbal cues and demonstrations. One way is to *give verbal cues along with a demonstration* to supplement the visual information (e.g., McCullagh, Stiehl, & Weiss, 1990; Zetou, Tzetzis, Vernadakis, & Kioumourtzoglou, 2002). When used this way, verbal cues aid in directing attention, and can guide rehearsal of the skill a person is learning. An example of a study showing the benefit of this use of

A CLOSER LOOK

Guidelines for Using Verbal Cues for Skill Instruction and Rehabilitation

- Cues should be short statements of one, two, or three words.
- Cues should relate logically to the aspects of the skill to be prompted by the cues.
- Cues can prompt a sequence of several movements.
- Cues should be limited in number. Cue only the most critical elements of performing the skill.
- Cues can be especially helpful for directing shifts of attention.
- Cues are effective for prompting a distinct rhythmic structure for a sequence of movements.
- Cues must be carefully timed so that they serve as prompts and do not interfere with performance.
- Cues should initially be spoken by the performer.

verbal cues was reported by Janelle, Champenoy, Coombes, and Mousseau, (2003) for learning a soccer accuracy pass. Non–soccer players who observed a skilled model video demonstration with accompanying verbal and visual cues learned the pass with more appropriate form and outcome accuracy than in five other practice conditions. The verbal cues, which were presented by audiotape along with the video, were short descriptions of the specific movement characteristics of the critical areas of the kick. The visual cues were arrows on the video that pointed to the critical areas of the kick. The comparison practice conditions involved discovery learning (i.e., they were told the accuracy goal of the skill but had to "discover" the best way to pass the ball to achieve the goal), verbal instructions only, a skilled model video demonstration with the visual cues, a skilled model video demonstration with the verbal cues, and a skilled model video demonstration only. Note that in this study the addition of visual cues enhanced the benefit of the verbal cues. Together, the visual arrows and the verbal cues focused the participants' attention to the parts of the skill that were critical to successful performance.

Verbal cues that focus attention while performing. Another way to use verbal cues is to *give cues to help learners focus on critical parts of skills.* For example, in an experiment by Masser (1993), first-grade classes were taught to do headstands. In one class, before students made each attempt to swing their legs up into the headstands, the instructor said, "Shoulders over your knuckles," to emphasize the body position critical to performing this skill. The cued students maintained their acquired skill three months after practice, whereas the students who had not received this verbal cue performed the headstand poorly three months later. A similar result occurred in an experiment using verbal cues to emphasize critical parts of the forward roll.

Verbal cues as prompts. Performers also can *use verbal cues while performing* to prompt themselves to attend to or perform key aspects of skills. Cutton and Landin (1994) provided a research example demonstrating the effectiveness of this technique for nonskilled individuals. Instructors taught university students in a beginning tennis class five verbal cues to say out loud each time they were required to hit a ball. These were as follows: "ready," to prompt preparation for the oncoming ball; "ball," to focus attention on the ball itself; "turn," to prompt proper body position to hit the ball, which included turning the hips and shoulders to be perpendicular with the net and pointing the racquet toward the back fence; "hit," to focus attention on contacting the ball; and "head down," to prompt the stationary position of the head after ball contact. The students who used

verbal cues short, concise phrases that direct a performer's attention to important environmental regulatory characteristics, or that prompt the person to perform key movement pattern components of skills.

verbal cues learned tennis groundstrokes better than those who did not, including a group that received verbal feedback during practice.

Verbal cues aid skilled performance. Verbal cues have also been used to *improve the performance of skilled athletes*. For example, Landin and Hebert (1999) had university female varsity tennis players use self-cueing to help them improve their volleying skills. Players learned to say the word "split," to cue them to hop to a balanced two-foot stop that would allow them to move in any direction. Then, they said, "turn," to cue them to turn their shoulders and hips to the ball. Finally, they said, "hit," to direct their attention to tracking the ball to the point of contact on the racquet and to cue themselves to keep the head still and hit the ball solidly. After practicing this cueing strategy for five weeks, the players showed marked improvements in both performance and technique.

The purposes of verbal cues. The various uses of verbal cues just described indicate that verbal cues can be used for two different purposes. Sometimes the cue *directs attention* to a specific environmental event or to specific sources of regulatory information (in our example, "ready," "ball," and "hit" are such cues). In other cases, the cue *prompts action*, for either a specific movement ("head down") or a sequence of movements ("turn"). The key to the effectiveness of verbal cues is that as the person practices and continues to use the cues, an association develops between the cue and the act it prompts. The benefit is that the person does not need to give attention to a large number of verbal instructions and can focus attention on the important perceptual and movement components of the skill.

SUMMARY

In this chapter, we discussed demonstration and verbal instructions and cues as effective means of communicating information about how to perform motor skills.

Demonstration

- A benefit of observing a skilled demonstration is that the observer detects the invariant characteristics of the movement pattern involved in the performance of the skill.
- The point-light technique and research about what an observer perceives from a skilled demonstration shows that demonstration tends to be a more effective means of instruction when the skill being learned requires a new movement coordination than when it involves a new parameter of a well-learned coordination pattern.
- Observation by a beginner of another beginner practicing a skill can facilitate skill learning.
- Skills should be demonstrated several times before a beginner practices a skill, with additional demonstrations during practice as needed.
- Auditory forms of demonstration are effective for the learning of motor skills that have a specific overall movement time goal or require a specific rhythmic sequence or beat.
- Two prominent theoretical views that propose explanations for the benefit of demonstration on skill learning are
  - ▸ The *cognitive mediation theory,* which proposes that observation of a demonstration leads to the development of a memory representation of the observed skill that the performer must access prior to performing the skill.
  - ▸ The *dynamic view* which proposes that people do not need cognitive mediation because the visual system can constrain the motor control system to act according to what has been observed.

Verbal Instructions and Cues

- Several attention-related factors are important to consider when using verbal instructions to communicate how to perform a motor skill:
  - ▸ The amount of information included in verbal instructions should take into account learners' attention-capacity limitations.
  - ▸ According to the action effect hypothesis, verbal instructions should direct the learner's focus of attention to movement outcomes rather than to the movements themselves.
  - ▸ Novice learners can learn invariant environmental context regulatory conditions without conscious awareness of them (i.e., implicit learning), although attention focus on the environmental context is important.
  - ▸ Instructions influence the novice learner to direct attention to certain performance goals, which influences the strategies the learner uses to begin practicing a skill.
- Verbal cues are short concise phrases that serve to
  - ▸ Direct the performer's attention to regulatory conditions in the environmental context.
  - ▸ Prompt key movement components of skills.
- Verbal cues can be given by an instructor or the performer to
  - ▸ Direct an observer's attention during a demonstration of a skill.
  - ▸ Direct a performer's attention to critical parts of skills.
  - ▸ Prompt movements while performing a skill.

POINTS FOR THE PRACTITIONER

- Demonstrations by a skilled model have their greatest influence on skill learning when the skill requires the learning of a new movement coordination pattern.
- People who are in the initial stage of learning a skill can benefit from observing others who are also novices. Consider using this strategy with large groups by having the people work in pairs where one practices the skill for several trials while the other observes, and then they switch roles.
- A demonstration by a skilled model can be done by the practitioner, a person in the group who can perform the skill well, or a skilled model on a video.
- Frequent demonstrations result in better learning than less frequent demonstrations, especially in the initial stage of learning.
- Be certain that the people observing a demonstration can see the critical features of the skill being demonstrated.
- If visual and/or verbal cues are used with a demonstration, keep them simple and focused on the critical features of the skill that need to be emphasized. Avoid providing a running verbal commentary along with a demonstration.
- Use auditory cues to demonstrate timing and rhythm characteristics of skills.
- Verbal instructions should present the minimum amount of information necessary to communicate what a person needs to do to perform a skill. Providing too much information in verbal instructions can be like providing no verbal instructions at all.
- Provide verbal instructions that focus attention on the outcome of a movement rather than on the movement itself.
- When teaching open skills, provide verbal instructions that focus attention on areas in the environmental context where critical invariant regulatory conditions can be observed. Expect that the detection and perception of much of this critical information will occur without the person's conscious awareness of what he or she perceives.
- To ensure the detection and perception of critical invariant regulatory conditions, allow the person to perform the skill in a variety of environmental contexts and situations.
- Emphasize movement form rather than speed for a person's initial practice attempts when teaching a speed-accuracy skill.

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INTERNET RESOURCES

- To experience the speed-accuracy trade-off phenomenon and how you can influence it by emphasizing speed or accuracy, as well as improve your keyboarding skills, go to http://www.typingmaster.com/support/intra/user_manual.html.
- To read about the point-light technique and to see some examples, go to http://astro.temple.edu/~tshipley/. Under Current Research Projects, click on Biological Motion. To view examples of a variety of movements in point-light displays, go to the Point-Light Archive part of this Web site.
- To watch a video about the discovery, characteristics, and importance of mirror neurons, go to http://www.pbs.org/wgbh/nova/sciencenow/video/3204/q01-220.html.
- To read about the availability of video demonstrations for
  - strength training and fitness activities, go to http://www.global-fitness.com/strength/s_video.html.
  - a wide variety of sports skills, go to http://www.sportsnationvideo.com/.
  - athletic trainers, go to http://www.athletictrainer.com/.

STUDY QUESTIONS

1. (a) What are two types of research evidence that show that observing a skilled demonstration of a motor skill influences the acquisition of the coordination characteristics of the skill? (b) Discuss what this research evidence tells us that we can apply to the use of demonstrations when teaching motor skills.
2. (a) Describe how observing an unskilled person learning a skill could help a beginner learn that skill. (b) Discuss why a learning benefit should result from a beginner observing another beginner learning a skill.
3. What are the main features of the two predominant theories about how observing a demonstration helps a person to learn that skill? How do these theories differ?

4. What is the action-effect hypothesis and how does it relate to instructions influencing *where* a person directs his or her attention when performing closed and open skills.
5. Describe two purposes for using verbal cues. Give an example for each.

Specific Application Problem:
Select a motor skill that you might teach in your future profession. Your supervisor has asked you to develop and defend a plan for providing information to the people you will work with about how to perform the skill. In your plan, describe the skill you will teach and relevant characteristics of the people you will teach, whether you will use demonstrations, verbal instructions, or both, and some specific characteristics of your choice. In your defense of this plan, emphasize why the information you will present and how you will deliver it would be preferable to other ways of providing these people with information about how to perform this skill.

CHAPTER 15

Augmented Feedback

Concept: Augmented feedback provides information that can facilitate skill learning.

After completing this chapter, you will be able to

- Distinguish between task-intrinsic feedback and augmented feedback as they relate to performing a motor skill
- Define *KR* and *KP* and give examples of each
- Describe skill learning conditions in which augmented feedback would or would not influence learning
- Compare and contrast quantitative and qualitative augmented feedback
- Describe situations in which various types of augmented feedback, such as videotape replay, movement kinematics, and biofeedback would be effective for facilitating skill learning
- Identify situations in which concurrent augmented feedback would be beneficial or detrimental to skill learning
- Describe two time intervals associated with the giving of terminal augmented feedback during practice and how their lengths and the activity during each influence skill learning
- Describe various ways to reduce the frequency of giving augmented feedback as ways to facilitate skill learning

APPLICATION

Think about a time when you were beginning to learn a new physical activity. How much success did you experience on your first few attempts? Most likely, you were not very successful. As you practiced, you probably had many questions that you needed someone to answer to help you better understand what you were doing wrong and what you needed to do to improve. Although you may have been able to answer many of your questions on your own as you continued to try different things while you practiced, you found that getting an answer from the instructor saved you time and energy.

This situation is an example of what we discussed in chapter 12 as typical in the early stage of learning a skill, or relearning a skill following an injury or illness. The significance of this example is that it points out that an important role played by the practitioner is to give augmented feedback to the learner to facilitate the skill acquisition process.

Consider the following situations. Suppose that you are teaching a golf swing or fitness activity to a class, helping a new student athletic trainer to tape an ankle, or working in a clinic with a patient learning to walk with an artificial limb. In each situation, the people practicing these skills can make lots of mistakes and will benefit from receiving augmented feedback.

When they make mistakes, which they do in abundance when they are beginners, how do you know which mistakes to tell them to correct on subsequent attempts? If you had a video camera available, would you videotape them and then let them watch their own performances? Or would it be even more beneficial to take the videotapes and have them analyzed so that you could show them what their movements looked like kinematically? There are many ways to provide augmented feedback. But before you use any one of these, you should know how to implement that method most effectively and when to use it to facilitate learning.

Application Problem to Solve Describe a motor skill that you might help people learn. Describe how you would give them feedback as they practice the skill and indicate why you would give feedback in this way and not in some other way.

DISCUSSION

When people perform a motor skill, they can have available to them *two general types of performance-related information (i.e., feedback)* that will "tell" them something about the outcome of the performance or about what caused that outcome. One is **task-intrinsic feedback,** which is the sensory-perceptual information that is a natural part of performing a skill. Each of the sensory systems can provide this type of feedback. We discussed three of these in chapter 6: touch, proprioception, and vision. For example, if a person throws a dart at a target on the wall, he or she receives *visual* task-intrinsic feedback from seeing the flight of the dart and where it lands on the target. In addition, the person receives *tactile and proprioceptive* task-intrinsic feedback movement of his or her body posture along with arm and hand movement as the person prepares to throw the dart and as the dart is thrown. Other sensory systems can also provide task-intrinsic feedback, as does the *auditory* system when the person hears the dart hit, or not hit, the target.

The second general type of performance-related information is *in addition to* task-intrinsic feedback. Although various terms have been used to identify this type of feedback, (*e.g., external feedback, task-extrinsic feedback*) the term that will be used in this book is **augmented feedback.** The adjective "augmented" refers to adding to or enhancing something, which in this case involves *adding to or enhancing task-intrinsic feedback.* It *enhances* the task-intrinsic feedback when augmented feedback provides information the person's sensory system can readily detect on its own. For example, a teacher or coach might tell a golfer where his or her hands were positioned at the top of the swing, even though proprioceptive feedback would allow the person to feel for himself or herself where they were. In a clinical environment, a therapist might show an amputee patient EMG traces on a computer monitor to enhance the patient's own proprioceptive feedback to help the patient activate appropriate muscles when learning to operate a prosthetic device.

In other situations, augmented feedback *adds* information that the person cannot detect using his or her sensory system. For example, the golf teacher or coach might tell the golfer where the ball went because the golfer was concentrating so much on keeping his or her head down during the swing that he or she did not see it after it was hit. Likewise, a therapist might tell a patient how much his or her body swayed because vestibular problems prevent the patient from being able to detect this information. In each of these situations, augmented feedback provides performance information that otherwise would not be available to the person.

task-intrinsic feedback the sensory feedback that is naturally available while performing a skill.

augmented feedback a generic term used to describe information about performing a skill that is added to sensory feedback and comes from a source external to the person performing the skill; it is sometimes referred to as extrinsic or external feedback.

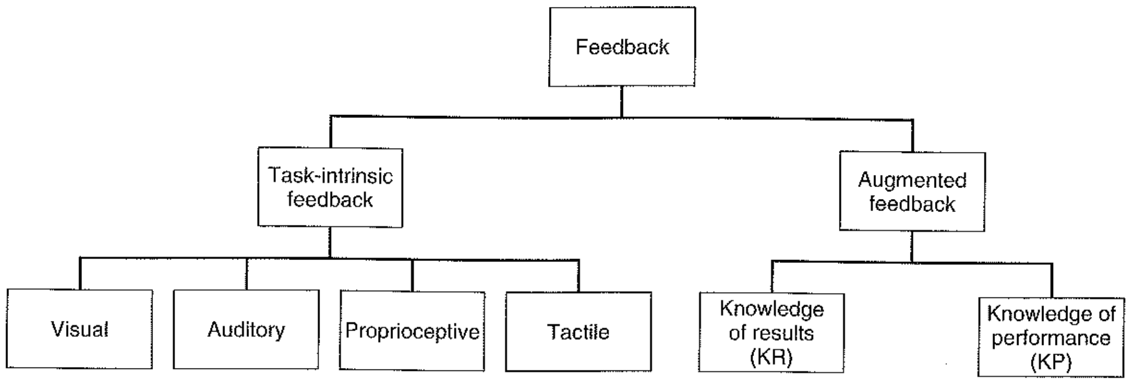


FIGURE 15.1 Illustration of the different types of feedback in the feedback family that are related to learning and performing motor skills.

THE FEEDBACK FAMILY

Note that the term *feedback* is common to both categories of performance-related information described in the preceding paragraphs. As a result, it is important to consider the term "feedback" as a generic term that describes information people receive about their performance of a motor skill during or after the performance. To help conceptualize the relationship between the two general types of performance-related feedback, consider these two types of feedback as related members of the same family. Figure 15.1 graphically describes the feedback family relationships for task-intrinsic feedback and augmented feedback, as well as for the related specific types of each.

TYPES OF AUGMENTED FEEDBACK

In Figure 15.1, note that there are *two categories of types of augmented feedback: knowledge of results* and *knowledge of performance.* Each category can involve a variety of ways of presenting augmented feedback; this will be the topic of discussion later in this chapter.

Knowledge of Results (KR)

The category of augmented feedback known as **knowledge of results** (commonly referred to as **KR**) consists of *externally presented information about the outcome of performing a skill or about achieving the goal of the performance.* In some situations, KR describes something about the performance outcome (i.e., result). For example, if a teacher tells a student in an archery class, "The shot was in the blue at 9 o'clock," the teacher is providing performance outcome information. Similarly, if a therapist shows a patient a computer-generated graph indicating that this leg extension was 3 degrees more than the last one, the therapist is giving KR to the patient about the outcome of his or her leg extension movement.

Sometimes, KR does not describe the performance outcome, but simply tells the performer whether he or she has achieved the performance goal. This is the case when some external device gives a "yes" or "no" signal indicating whether or not the performance goal was achieved. For example, to augment proprioceptive and visual feedback for a patient working on achieving a specific amount of leg extension, the therapist could set a buzzer to be activated when the patient achieved the goal number of degrees of movement. Although the buzzer would provide no information about how close to the goal or how far from it the movement was if it had not been achieved, the patient would know that he or she had not achieved the goal unless the buzzer sounded. There are some additional examples of KR in table 15.1.

It is important to point out that we are using the term KR to refer to a type of augmented feedback. Although a person can obtain knowledge about the results of an action from his or her own sensory system, such as seeing whether the basketball missed the basket or went in, this type of performance-related information is task-intrinsic. It does not refer to the specific type of performance-related information the term KR refers to in this text. The importance of this distinction is that it allows us to distinguish the specific influences of task-intrinsic and augmented feedback on skill learning.

Knowledge of Performance (KP)

The second category of augmented feedback is **knowledge of performance** (known as **KP**). This is information about the *movement characteristics that led to the performance outcome.* The important point here is that KP differs from KR in terms of which aspect of performance the information refers to. For example, in the archery situation described above, the teacher would provide KP by telling the student that he or she pulled the bow to the left at the release of the arrow. Here, the teacher augments the task-intrinsic feedback by telling the student what he or she did that caused the arrow to hit the target where it did.

In addition to giving KP verbally, there are various nonverbal means of providing KP. For example, video replay is a popular method of showing a person what he or she did while performing a skill. Video replay allows the person to see what he or she actually did that led to the outcome of that performance. Although video replay can show

TABLE 15.1 Examples of Augmented Feedback

• **A golf instructor tells a student:**	**KR** → "Your shot went into the right rough."
	KP → "You did not take your backswing back far enough before you began your downswing."
• **A physical therapist tells a patient:**	**KR** → "You walked 10 feet more today than you did yesterday."
	KP → "You should bend your knees more as you walk."
• **A student driver in a simulator**	**KR** → sees the number of errors he or she made after completing a session.
	KP → sees a light flash each time he or she makes an error while driving in a session.
• **A sprinter in track**	**KR** → sees a posting on the scoreboard of the amount of time to run the race.
	KP → sees a videotape replay of his or her race.
• **A gymnast**	**KR** → sees the judges' scores after completing a routine.
	KP → looks at a computer monitor to see a stick figure representation of his or her body, limb, and head displacement when he or she performed the routine.
• **A knee rehabilitation patient**	**KR** → reads a display on an exercise machine that indicates the number of degrees of leg extension he or she had on that leg extension exercise repetition.
	KP → hears a buzzer when a target muscle is active during a leg extension exercise.

knowledge of results (KR) category of augmented feedback that gives information about the outcome of performing a skill or about achieving the goal of the performance.

knowledge of performance (KP) category of augmented feedback that gives information about the movement characteristics that led to a performance outcome.

A CLOSER LOOK

Augmented Feedback as Motivation

An instructor can use augmented feedback to influence a person's perception of his or her own ability in a skill. This is an effective way to influence the person's motivation to continue pursuing a task goal or performing a skill. The verbal statement "You're doing a lot better" can indicate to a person that he or she is being successful at an activity. Evidence supporting the motivational effectiveness of this type of verbal feedback comes from research relating to self-efficacy and performance of skills.

For example, Solmon and Boone (1993) showed that in a physical education class environment, students with high ability perceptions demonstrated longer persistence at performing a skill and had higher performance expectations than those with low ability perceptions. In her reviews of self-efficacy research as it relates to skill performance, Feltz (1992; Feltz & Payment, 2005) concluded that the success or failure of past performance is a key mediator of a person's self-perceptions regarding ability.

Visual augmented feedback has also been shown to have motivational benefits for learning motor skills. An interesting example comes from its use in a physical therapy context. People with neurological gait disorders reported that the addition of visual augmented feedback about their performance on a Lokomat driven gait orthosis (a robotic-assisted gait training device) made them more motivated to train on the device than when this additional feedback was not provided (Banz, Bollinger, Colombo, Dietz, & Lünenburger, 2008).

An important implication of these findings is that the practitioner can present augmented feedback in a way that influences a person's feelings of success or failure which, in turn, influence a person to continue or to stop his or her involvement in participating in a physical activity.

a performance outcome, it is commonly used as KP. Another means of providing KP that is increasing in popularity as computer software becomes more accessible is showing the person computer-generated kinematic characteristics of the just-completed performance. In clinical environments, therapists also use biofeedback devices to give KP. For example, a therapist can attach a buzzer to an EMG recording device so that the person hears the buzzer sound when he or she activates the appropriate muscle during the performance of an action. In each of these situations, sensory feedback is augmented in a way that informs the person about the movement characteristics associated with the outcome of an action.

THE ROLES OF AUGMENTED FEEDBACK IN SKILL ACQUISITION

Augmented feedback plays two roles in the skill learning process. One is to *facilitate achievement of the action goal of the skill.* Because augmented feedback provides information about the success of the skill in progress or just completed, the learner can determine whether what he or she is doing is appropriate for performing the skill correctly. Thus, the augmented feedback can help the person achieve the skill goal more quickly or more easily than he or she could without this external information.

The second role played by augmented feedback is to *motivate the learner to continue striving toward a goal.* In this role, the person uses augmented feedback to compare his or her own performance to a performance goal. The person then must decide to continue trying to achieve that goal, to change goals, or to stop performing the activity. This motivational role of augmented feedback is not the focus of our discussion here. Others, however, have discussed it in the motor learning literature (e.g., Little & McCullagh, 1989). Scholars interested in the pedagogical aspects of physical education teaching (e.g., Solmon & Lee, 1996; Silverman, Woods, & Subramaniam, 1998) increasingly are studying the effects of augmented feedback on people's motivation to engage in, or continue to engage in, physical activities. In addition, augmented feedback functions as an important factor in influencing students' perceptions of ability (e.g., Fredenberg, Lee, & Solmon, 2001). And exercise psychologists have shown that augmented feedback is influential in motivating people to adhere to exercise and rehabilitation programs (e.g., Annesi, 1998; Dishman, 1993).

HOW ESSENTIAL IS AUGMENTED FEEDBACK FOR SKILL ACQUISITION?

When a researcher or practitioner considers the use of augmented feedback to facilitate skill acquisition, an important theoretical and practical question arises: *Is augmented feedback necessary for a person to learn motor skills?* The answer to this question has theoretical implications for the understanding of the nature of skill learning itself. The need, or lack of need, for augmented feedback to acquire motor skills tells us much about what characterizes the human learning system and how it functions to acquire new skills. From a practical perspective, determining the necessity for augmented feedback for skill learning can serve to guide the development and implementation of effective instructional strategies. As you will see, the answer to this question is not a simple yes or no. Instead, there are *four different answers.* Which one is appropriate depends on certain characteristics of the skill being learned and of the person learning the skill.

Augmented Feedback Can Be Essential for Skill Acquisition

In some skill learning situations, people, for various reasons, cannot use the task-intrinsic feedback to determine what they need to do to improve performance. As a result, augmented feedback is essential for learning. There are at least three types of situations in which a person may *not* be able to use important task-intrinsic feedback effectively.

First, some skill performance contexts do not make critical sensory feedback available to the person. For example, when a performer cannot see a target that he or she must hit, the performer does not have important visual feedback available. In this case, augmented feedback adds critical information that is not available from the task performance environment itself.

Second, because of injury, disease, and the like, the person does not have available the sensory pathways needed to detect critical task-intrinsic feedback for the skill he or she is learning. For these people, augmented feedback serves as a substitute for this missing information.

Third, in some situations the appropriate task-intrinsic feedback provides the necessary information and the person's sensory system is capable of detecting it, but the person cannot use the feedback. For example, a person learning to extend a knee a certain distance or to throw a ball at a certain rate of speed may not be able to determine the distance moved or the rate of speed of the throw because of lack of experience. In these situations, augmented feedback helps to make the available task-intrinsic feedback more meaningful to the performer.

Augmented Feedback May Not Be Needed for Skill Acquisition

Some motor skills *inherently provide sufficient task-intrinsic feedback,* so augmented feedback is redundant. For these types of skills, learners can use their own sensory feedback systems to determine the appropriateness of their movements and make adjustments on future attempts. An experiment by Magill, Chamberlin, and Hall (1991) provides a laboratory example of this type of situation. Participants learned a coincidence-anticipation skill in which they simulated striking a moving object, which was a series of LEDs sequentially lighting along a 281 cm long trackway. As they faced the trackway, they had to use a handheld bat to knock down a small wooden barrier directly under a target LED coincident with the lighting of the target. KR was the number of msec that they contacted the barrier before or after the target lighted. Four experiments showed that participants learned this task regardless of the number of trials on which they received KR during practice. In fact, receiving KR during practice did not lead to better learning than practice without KR.

A CLOSER LOOK

Teacher Feedback Relationships in Physical Education Classes

Silverman, Woods, and Subramaniam (1999) examined the relationship between teacher feedback and several different practice and performance characteristics for eight classes of middle school physical education. Although each teacher taught one activity, the eight classes involved a variety of activities: volleyball, soccer, badminton, basketball, and ultimate. The teachers were videotaped for two classes in a row in which motor skill was the focus of instruction. The researchers observed the videotapes and recorded characteristics of several different teacher behavior categories, including teacher feedback. Among the various results of the analysis of the data from this study was the finding that *the amount of teacher feedback given to students was significantly correlated with the amount of appropriate practice in which students engaged,* regardless of skill level. These results indicate that even though research has shown that teacher feedback and skill achievement are not highly correlated, teacher feedback has a positive impact on the students' participation in class by influencing them to engage in activity that is appropriate for helping them learn the skills that are the focus of the class instruction.

A motor skill that does not require augmented feedback to learn it has an important characteristic: *a detectable external referent* in the environment that the person can use to determine the appropriateness of an action. For the anticipation timing task in the Magill et al. experiment, the target and other LEDs were the external referents. The learner could see when the bat made contact with the barrier in comparison to when the target lighted; this enabled him or her to see the relationship between his or her own movements and the goal of those movements. It is important to note here that the learner may *not* be consciously aware of this relationship. The sensory system and the motor control system operate in these situations in a way that does not demand the person's conscious awareness of the environmental characteristics (see Magill, 1998). Thus, the enhancement of these characteristics by providing augmented feedback does not increase or speed up learning of the skill.

Practice condition characteristics also influence the need for augmented feedback. One of these characteristics is the existence of an observational learning situation, which we discussed in chapter 14. Two different types of observational learning situations can be influential. In one, the learner observes a skilled model perform the skill. For example, in an experiment by Magill and Schoenfelder-Zohdi (1996), people who observed a skilled demonstration learned a rhythmic gymnastics rope skill as well as those who received verbal KP after each trial. In the other situation, the learner observes other beginners practice. For example, Hebert and Landin (1994) showed that beginning tennis players who watched other beginners practice learned the tennis forehand volley as well as or better than beginning players who received verbal KP. In both of these situations, beginners were able to practice and improve without augmented feedback.

There is an interesting parallel between skill learning situations in which learners do not need augmented feedback and results of studies investigating the use of teacher feedback in physical education class settings. These studies consistently have shown low correlations for the relationship between teacher feedback and student achievement (e.g., Lee, Keh, & Magill, 1993; Silverman, Tyson, & Krampitz, 1991). This finding suggests that the amount and quality of teacher feedback is influential for improving the skills of beginners in sport skills class settings, but we should not see it as the most important variable. Other variables, such as observational learning, appear to be capable of precluding the need for augmented feedback. Our understanding of the extent of this influence awaits further research.

Augmented Feedback Can Enhance Skill Acquisition

There are some types of motor skills that people can learn without augmented feedback, but they will *learn them more quickly or perform them at a higher level* if they receive augmented feedback during practice. For these skills, augmented feedback is neither essential nor redundant. Instead, it *enhances the learning of these skills beyond what could be achieved without augmented feedback.*

Skills in this category include those for which improvement does occur through task-intrinsic feedback alone, but because of certain skill or learner characteristics, performance improvement reaches only a certain level. One type of skill that fits this description consists of relatively simple skills for which achievement of the performance goal is initially easy to attain. An example is a movement goal of moving as quickly as possible. Initially, a person can assess if a particular attempt was faster than a previous one. However, improvement seems to stop at a certain level of performance usually because the learner's lack of experience results in his or her decreased capability to discriminate small movement-speed differences. To improve beyond this level of performance, the person requires augmented feedback.

Another type of skill for which augmented feedback enhances learning is any complex skill that requires a person to acquire an appropriate multilimb pattern of coordination. For such skills, learners can attain a certain degree of success simply by making repeated attempts to achieve the performance goal. But this goal achievement process can be speeded up with the addition of KP. More specifically, the KP that works best is information about critical components of the coordination pattern.

The best research example of this type of skill is an experiment by Wallace and Hagler (1979). Participants learned a one-hand basketball set shot with the nondominant hand, from a distance of 3.03 m from the basket, and 45 degrees to the left side of the basket. After each shot, one group received verbal KP about errors in their stance and limb movements during the shot. Another group received only verbal encouragement after each shot. Both groups could see the outcome of each shot. Figure 15.2 depicts the results. Note that KP provided an initial boost in performance for the first fifteen trials. Then, the verbal encouragement group caught up. However, similarity in performance between the two groups lasted only about ten trials; after this point, the verbal encouragement group showed no further improvement, whereas the group receiving KP continued to improve.

Augmented Feedback Can Hinder Skill Learning

An effect of augmented feedback on skill learning that many might not expect is that it can hinder the learning process and, in some cases, actually make learning worse than it would have been otherwise. This effect is especially evident when a beginning learner becomes dependent on augmented feedback that will not be available in a test situation. Typically, the performance improvement the learner experienced during practice deteriorates in the test situation. In fact, in some situations, not only does performance deteriorate when augmented feedback is withdrawn, but the test performance is no better than if augmented feedback had not been given at all.

The characteristic of tasks that is the most likely to lead to a dependency on augmented feedback is task-intrinsic feedback that is minimal or difficult to interpret. When performing these types of tasks, people typically substitute augmented feedback for task-intrinsic feedback, because it gives them an easy-to-use guide for performing correctly.

Several types of situations can lead a person to become dependent on augmented feedback. We will discuss three later in this chapter. One concern is the presentation of erroneous augmented feedback. Another situation involves the presentation of concurrent augmented feedback, which refers to giving augmented feedback while a person performs a skill. The third occurs when augmented feedback is given too frequently during practice.

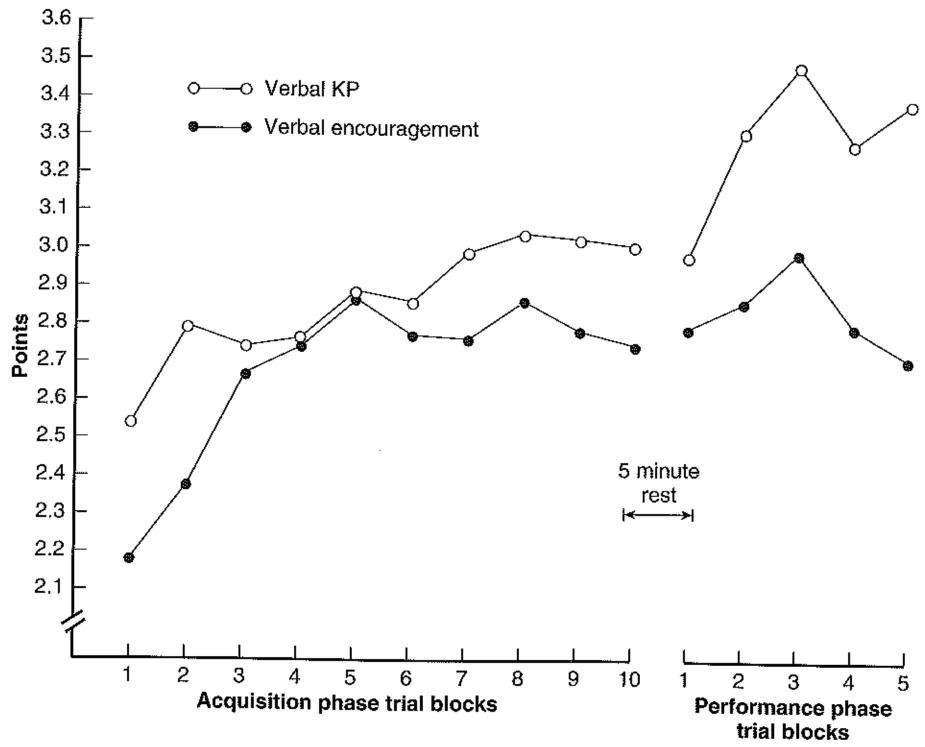


FIGURE 15.2 Results of the experiment by Wallace and Hagler showing the benefit of verbal KP for learning a basketball shooting skill. [Reprinted with permission from *Research Quarterly for Exercise and Sport, Vol. 50, No. 2,* 265–271. Copyright © 1979 by the American Alliance for Health, Physical Education, Recreation and Dance, 1900 Association Drive, Reston, VA 20191.]

THE CONTENT OF AUGMENTED FEEDBACK

In this section, we will focus on important issues concerning the content of augmented feedback, and then examine several types of augmented feedback that practitioners can use. We will consider five issues related to the content of augmented feedback. Each of these concerns some of the kinds of information augmented feedback may contain.

Information about Errors versus Correct Aspects of Performance

An often debated issue about augmented feedback content is whether the information the instructor conveys to the learner should refer to the mistakes he or she has made or those aspects of the performance that are correct. Research evidence consistently has shown that *error information is more effective for facilitating skill learning,* especially in terms of durability and transfer capability. This evidence supports an important hypothesis, that focusing on what is done correctly while learning a skill, especially in the early stage of learning, is not sufficient by itself to produce optimal learning. Rather, the experience the person has in correcting errors by operating on error-based augmented feedback is especially important during skill acquisition to enhance performance of the skill in different environments and situations, as well as to enhance the capability to self-correct errors while performing the skill.

Another way of looking at this issue is to consider the different roles augmented feedback plays. Error information directs a person to change certain

A CLOSER LOOK

KP about Certain Features of a Skill Helps Correct Other Features

Participants in an experiment by den Brinker, Stabler, Whiting, and van Wieringen (1986) learned to perform on the slalom ski simulator, like the one illustrated in the preceding chapter in figure 14.2. Their three-part goal was to move the platform from left to right as far as possible at a specific high frequency, and with a motion that was as fluid as possible. On the basis of these performance goals, three groups received different types of information as KP after each trial: the *distance* they had moved the platform, how close they were to performing at the criterion platform movement *frequency,* and how fluid their movements were (i.e., *fluency*). All three groups practiced for four days, performing six 1.5 min trials each day, with a test trial before and after each day's practice trials.

Early in practice, the type of KP an individual received influenced only the performance measure specifically related to that feature of performing the skill. However, on the last two days of practice, KP about *distance caused people to improve all three performance features*. Thus, giving KP about one performance feature led to improvement not only of that one, but also of the two other performance features.

performance characteristics; this in turn facilitates skill acquisition. On the other hand, information indicating that the person performed certain characteristics correctly tells the person that he or she is on track in learning the skill and encourages the person to keep trying. When we consider augmented feedback from this perspective, we see that whether this feedback should be about errors or about correct aspects of performance depends on the goal of the information. Error-related information works better to facilitate skill acquisition, whereas information about correct performance serves better to motivate the person to continue.

KR versus KP

Two relevant questions concerning the comparison of the use of KR and KP in skill learning situations are these: Do practitioners use one of these forms of augmented feedback more than the other? Do they influence skill learning in similar or different ways?

Most of the evidence addressing the first question comes from the study of physical education teachers in actual class situations. The best example is a study by Fishman and Tobey (1978). Although their study was conducted many years ago, it is representative of more recent studies, and it involves the most extensive sampling of teachers and classes of any study that has investigated this question. Fishman and Tobey observed teachers in eighty-one classes teaching a variety of physical activities. The results showed that the teachers overwhelmingly gave KP (94 percent of the time) more than KR.

An answer to the second question, concerning the relative effectiveness of KR and KP, is more difficult to provide because of the lack of sufficient and conclusive evidence from research investigating this question. The following examples of experiments provide some insight into a reasonable answer.

Two of the experiments suggest that KP is better than KR to facilitate motor skill learning. Kernodle and Carlton (1992) compared KR with videotape replays and verbally presented technique statements as KP in an experiment in which participants practiced throwing a soft, spongy ball as far as possible with the nondominant arm. KR was presented as the distance of the throw for each practice trial. The results showed that KP led to better throwing technique and distance than KR. Zubiaur, Oña, and Delgado (1999) made a similar conclusion in a study in which university students with no previous volleyball experience practiced the overhead serve in volleyball. KP was specific information about the most important error to correct as it related to action either before hitting or in hitting the ball. KR referred to the outcome of the hit in terms of the ball's spatial precision, rotation, and flight. The results indicated that KP was more influential for learning the serve.

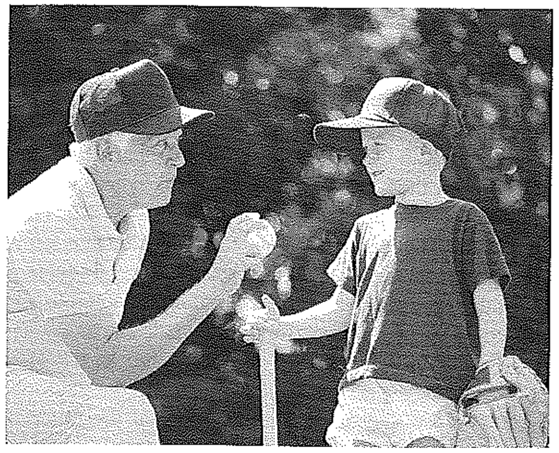
However, a study by Silverman, Woods, and Subramaniam (1999) provided evidence for the benefit of both KR and KP in terms of how each related to how often students in physical education classes would engage in successful and unsuccessful practice trials during a class. They observed eight middle school teachers teaching two classes each in various sport-related activities. The results indicated that teacher feedback as KR and as KP showed relatively high correlations with the frequency of students engaging in successful practice trials (.64 and .67, respectively).

These studies indicate that *both KR and KP can be valuable* for skill learning. With this in mind, consider the following hypotheses about conditions in which each of these forms of augmented feedback would be beneficial. *KR will be beneficial for skill learning* for at least four reasons: (1) Learners often use KR to confirm their own assessments of the task-intrinsic feedback, even though it may be redundant with task-intrinsic feedback. (2) Learners may need KR because they cannot determine the outcome of performing a skill on the basis of the available task-intrinsic feedback. (3) Learners often use KR to motivate themselves to continue practicing the skill. (4) Practitioners may want to provide only KR in order to establish a discovery learning practice environment in which learners are encouraged to engage in problem-solving activity by making trial and error as the primary means of solving the problem of how to perform a skill to achieve its action goal.

On the other hand, *KP can be especially beneficial* when (1) skills must be performed according to specified movement characteristics, such as gymnastics stunts or springboard dives; (2) specific movement components of skills that require complex coordination must be improved or corrected; (3) the goal of the action is a kinematic, kinetic, or specific muscle activity; (4) KR is redundant with the task-intrinsic feedback.

Qualitative versus Quantitative Information

Augmented feedback can be qualitative, quantitative, or both. If the augmented feedback involves a numerical value related to the magnitude of some



When giving verbal KP, it is important to provide information that is meaningful to the person to whom it is given.

performance characteristic, it is called **quantitative augmented feedback.** In contrast, **qualitative augmented feedback** is information referring to the quality of the performance characteristic without regard for the numerical values associated with it.

For *verbal augmented feedback,* it is easy to distinguish these types of information in performance situations. For example, a therapist helping a patient to increase gait speed could give that patient qualitative information about the latest attempt in statements such as these: "That was faster than the last time"; "That was much better"; or "You need to bend your knee more." A physical education teacher teaching a student a tennis serve could tell the student that a particular serve was "good," or "long," or could say something like this: "You made contact with the ball too far in front of you." On the other hand, the therapist could give the patient quantitative verbal augmented feedback using these words: "That time you walked 3 seconds faster than the last time," or, "You need to bend your knee 5 more degrees." The teacher could give quantitative feedback to the tennis student like this: "The serve was 6 centimeters too long," or "You made contact with the ball 10 centimeters too far in front of you."

Practitioners also can give quantitative and qualitative information in *nonverbal forms of augmented feedback.* For example, the therapist could

give qualitative information to the patient we have described by letting him or her hear a tone when the walking speed exceeded that of the previous attempt or when the knee flexion achieved a target amount. The teacher could give the tennis student qualitative information in the form of a computer display that used a moving stick figure to show the kinematic characteristics of his or her serving motion. Those teaching motor skills often give nonverbally presented quantitative information in combination with qualitative forms. For example, the therapist could show a patient a computer-based graphic representation of his or her leg movement while walking along, displaying numerical values of the walking speeds associated with each attempt or the degree of knee flexion observed on each attempt. We could describe similar examples for the tennis student.

How do these two types of augmented feedback information influence skill learning? Although the traditional view is that quantitative augmented feedback is preferred, results from an experiment by Magill and Wood (1986) suggest a different conclusion. Each participant practiced moving his or her arm through a series of wooden barriers to produce a specific six-segment movement pattern. Each segment had its own criterion movement time, which participants had to learn. Performance for the first sixty trials showed no difference between qualitative and quantitative forms of KR. However, during the final sixty trials and on the twenty no-KR retention trials, quantitative KR resulted in better performance than qualitative.

These results suggest that people in the early stage of learning give attention primarily to the qualitative information, even when they have quantitative information available. The advantage of this attention focus is that the qualitative information provides an easier way to make a first approximation of the required movement. Put another way, this information allows learners to perform an action that is "in the ballpark" of what they need to do, which, as we discussed in chapter 12, is an important goal for the first stage of learning. After they achieve this "ballpark" capability, quantitative information becomes more valuable to them, because it enables them to refine characteristics of performing the skill that lead to more consistent and efficient achievement of the action goal.

Augmented Feedback Based on Error Size

A question that has distinct practical appeal is this: How large an error should a performer make before the instructor or therapist gives augmented feedback? To many, it seems reasonable to provide feedback only when errors are large enough to warrant attention. This approach suggests that in many skill learning situations, practitioners develop **performance bandwidths** that establish performance error tolerance limits specifying when they will or will not give augmented feedback. When a person's performance is acceptable (i.e., within the tolerance limits of the bandwidth) the practitioner does not give feedback. But if the performance is not acceptable (i.e., the amount or type of error is outside the bandwidth) the practitioner gives feedback.

Research supports the effectiveness of the performance bandwidth approach. For example, in the first reported experiment investigating this procedure, Sherwood (1988) had participants practice a rapid elbow-flexion task with a movement-time goal of 200 msec. One group received KR about their movement-time error after every trial, regardless of the amount of error (i.e., 0 percent bandwidth). Two other groups received KR only when

quantitative augmented feedback augmented feedback that includes a numerical value related to the magnitude of a performance characteristic (e.g., the speed of a pitched baseball).

qualitative augmented feedback augmented feedback that is descriptive in nature (e.g., using such terms as *good, long*), and indicates the quality of performance.

performance bandwidth in the context of providing augmented feedback, a range of acceptable performance error; augmented feedback is given only when the amount of error is greater than this range.

A CLOSER LOOK

Quantitative versus Qualitative Augmented Feedback and the Performance Bandwidth Technique

Cauraugh, Chen, and Radlo (1993) had subjects practice a timing task in which they had to press a sequence of three keys in 500 msec. Participants in one group received quantitative KR about their movement times (MT) when MT was *outside* a 10 percent performance bandwidth. A second group, in the reverse of that condition, received quantitative KR only when MT was *inside* the 10 percent performance bandwidth. Two additional groups had participants "yoked" to individual participants in the outside and inside bandwidth conditions. Members of these two groups received KR on the same trials their "yoked" counterparts did. This procedure provided a way to have two conditions with the same frequency of augmented feedback, while allowing a comparison between bandwidth and no-bandwidth conditions.

In terms of KR frequency, those in the outside bandwidth condition received quantitative KR on 25 percent of the sixty practice trials; those in the inside condition received KR on 65 percent of the trials. The interesting feature of this difference is that the remaining trials for both groups were implicitly qualitative KR trials, because when they received no KR, the participants knew that their performance was "good" or "not good." The retention test performance results showed that the two bandwidth conditions did not differ, but both yielded better learning than the no-bandwidth conditions. These results show that establishing performance bandwidths as the basis for providing quantitative KR yields an interplay between quantitative and qualitative KR that facilitates skill learning.

their error exceeded bandwidths of 5 percent and 10 percent of the goal movement time. The results of a no-KR retention test showed that the 10 percent bandwidth condition resulted in the least amount of movement time variability (i.e., variable error), whereas the 0 percent condition resulted in the most variable error. Other researchers have replicated these results (e.g., Lee, White, & Carnahan, 1990; Cauraugh, Chen, & Radlo, 1993).

A practical issue concerning the use of the bandwidth technique relates to the instructions provided about the bandwidth procedure. This issue is relevant because when the learners receive no augmented feedback about their performance, the implicit message is that it was "correct." There is an instruction-related question here: Is it important that the learner explicitly be told this information, or will the learner implicitly learn this information during practice? According to the results of an experiment by Butler, Reeve, and Fischman (1996), the bandwidth technique leads to better learning when the participants know in advance that not receiving KR means they are essentially "correct."

Erroneous Augmented Feedback

One of the ways augmented feedback hinders learning is by providing people with erroneous information. While this statement may seem unnecessary because it makes such common sense, the statement gains importance when it is considered in the context of practicing a skill that can be learned *without* augmented feedback. In this skill learning situation, augmented feedback is redundant with the information available from task-intrinsic feedback. As a result, most people would expect that to provide augmented feedback would be a waste of time because it would not influence the learner. But research evidence shows that this is not the case, because even when augmented feedback is redundant information, beginners will use it rather than ignore it.

The first evidence of this type of effect was reported by Buekers, Magill, and Hall (1992). Participants practiced an anticipation timing task similar to the one used by Magill, Chamberlin, and Hall (1991), which was described earlier in this chapter as a task for which KR is not needed to learn the task.

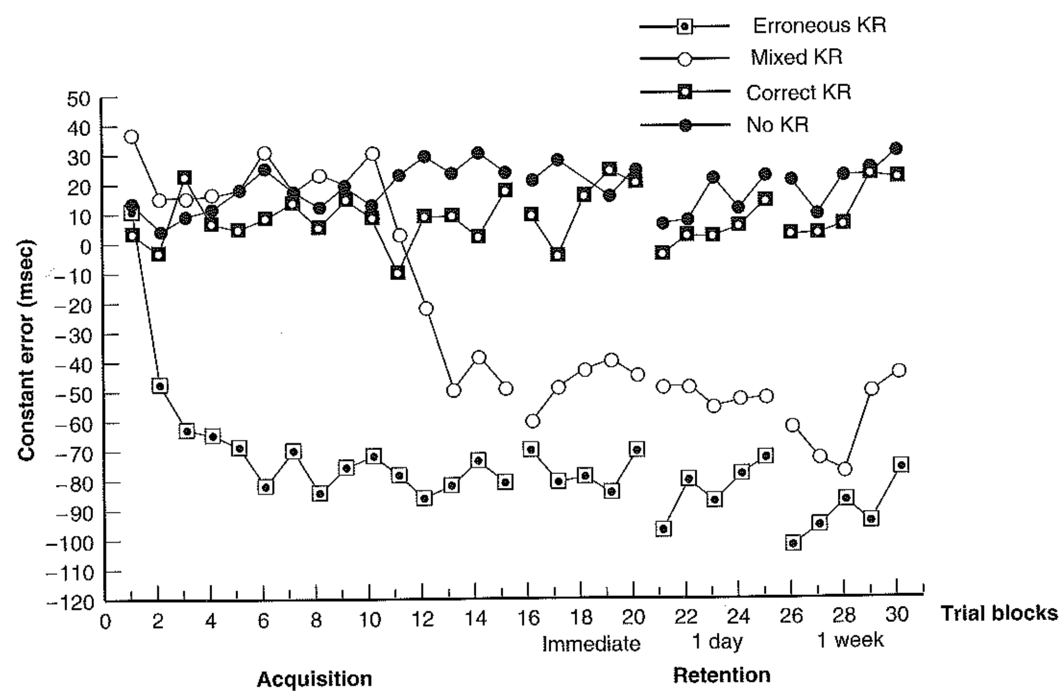


FIGURE 15.3 Results of the experiment by Buekers et al., showing the effects of erroneous KR compared to no KR and correct KR for learning an anticipation timing skill. Note that participants in the mixed-KR group received correct KR for their first fifty trials and then received erroneous KR for their last twenty-five practice trials. [From Buekers, M. J., Magill, R. A., & Hall, K. G. (1992). The effect of erroneous knowledge of results on skill acquisition when augmented information is redundant. *Quarterly Journal of Experimental Psychology, 44 (A)*, 105–117. Reprinted by permission of The Experimental Psychology Society.]

In the Buekers et al. experiment, three of four groups received KR after every trial. The KR was displayed on a computer monitor and indicated to the participants the direction and amount of their timing error. For one of these groups, KR was always correct. But for another group, KR was always erroneous by indicating that performance on a trial was 100 msec later than it actually was. The third KR group received correct KR for the first fifty trials, but then received the erroneous KR for the last twenty-five trials. A fourth group did not receive KR during practice.

The results (figure 15.3) showed two important findings. First, the correct-KR and the no-KR groups did not differ during the practice or the retention trials, which confirmed previous findings that augmented feedback is not needed to learn this skill. Second, the erroneous KR information led participants to learn to perform according to the KR rather than according to the task-intrinsic feedback. This latter result suggested that the *participants used KR, even though it was erroneous information.* Even more impressive was that the erroneous KR influenced the group that had received correct KR for fifty trials and then was switched to the erroneous KR. After the switch, this group began to perform similarly to the group that had received the incorrect KR for all the practice trials. In addition, the erroneous information not only influenced performance when it was available but also influenced retention performance one day and one week later on no-KR. A subsequent experiment (McNevin, Magill, & Buekers, 1994) demonstrated that the erroneous KR also influenced performance on a no-KR transfer test in which participants were required to respond to a faster or slower speed than they practiced.

The preceding demonstrations of erroneous KR effects were based on laboratory tasks, but similar results have been shown for sports skills. For example, an experiment by Ford, Hodges, and Williams (2007) had skilled soccer players kicking a ball to a target, which required that the ball achieve a specific height during its flight. One group of players received erroneous KR about the height of the ball's flight during each kick by observing a prerecorded video clip of a kicked ball that reached a height that was different from their own. Results showed that the players eventually based the height of their kicks on the erroneous video feedback rather than on their own sensory feedback.

Why would erroneous KR affect learning a skill for which KR is redundant information? The most likely reason appears to be that when people perform skills, they rely on augmented feedback to help them deal with their uncertainty about what the task-intrinsic feedback is telling them. For the anticipation timing and soccer kicking tasks, the uncertainty may exist because the visual task-intrinsic feedback is difficult to consciously observe, interpret, and use. Evidence for an uncertainty-based explanation has been demonstrated in experiments by Buekers, Magill, and Sneyers (1994), and Buekers and Magill (1995).

The important message for practitioners here is that people, especially those who are in the early stage of skill learning, will use augmented feedback when it is available, whether it is correct or not. Because of their uncertainty about how to use or interpret task-intrinsic feedback, beginners rely on augmented feedback as a critical source of information on which to base how they will move corrections on future trials. As a result, instructors need to be certain that they provide correct augmented feedback.

TYPES OF KNOWLEDGE OF PERFORMANCE

Most of the research on which we base our knowledge of augmented feedback and skill learning comes from laboratory experiments in which researchers gave KR to participants. Although most of the conclusions from that research also apply to KP, it is useful to look at some of the research that has investigated different types of KP.

> **LAB LINKS**
>
> Lab 15a in the Online Learning Center Lab Manual provides an opportunity for you to develop a priority list of KP statements that you might give as feedback to people learning or relearning a motor skill.

Verbal KP

One of the reasons practitioners give verbal KP more than verbal KR is that KP gives people more information to help them improve the movement aspects of skill performance. One of the problems that arises with the use of verbal KP is determining the appropriate content: what to tell the person practicing the skill. This problem occurs because skills are typically complex and KP usually relates to a specific feature of skill performance. The challenge for the instructor or therapist, then, is selecting the appropriate features of the performance on which to base KP.

Selecting the skill component for KP. The first thing the practitioner must do is perform a *skill analysis* of the skill being practiced. This means identifying the various component parts of the skill. Then, he or she should prioritize each part in terms of how critical that part is for performing the skill. Prioritize by listing the most critical part first, then the second most critical, and so on. To determine which part is most critical, decide which part of the skill absolutely must be done properly for the person to achieve the skills action goal. For example, for the skill of throwing a dart at a target, the most critical component is looking at the target. This part is the most critical because even if a beginner did all other parts of the skill correctly (which would be unlikely), there is a very low chance that he or she would throw the dart accurately without looking at the target. In this case, then, looking at the target would be first on the skill analysis priority list, and would be the first part of the skill assessed in determining what to give KP about. (For two examples of research reporting the use and benefit of a skill analysis approach to selecting skill components as the basis for verbal KP, see Magill & Schoenfelder-Zohdi, 1996; Weeks & Kordus, 1998).

> **A CLOSER LOOK**
>
> **An Example of Basing Verbal KP on a Skill Analysis**
>
> In an experiment by Weeks and Kordus (1998), twelve-year-old boys who had no previous experience in soccer practiced a soccer throw-in. The participants' goal was to perform throw-ins as accurately as possible to a target on the floor. The distance to the target was 75 percent of each participant's maximum throwing distance. They received verbal KP on one of eight aspects of technique, which the researchers referred to as "form." Which aspect of form each participant received was based on the primary form problem identified for a throw-in. The researchers constructed a list of eight "form cues" on the basis of a skill analysis of the throw-in and used this list to give verbal KP. The eight form cues were these:
>
> 1. The feet, hips, knees, and shoulders should be aimed at the target, feet shoulder width apart.
> 2. The back should be arched at the beginning of the throw.
> 3. The grip should look like a "W" with the thumbs together on the back of the ball.
> 4. The ball should start behind the head at the beginning of the throw.
> 5. The arms should go over the head during the throw and finish by being aimed at the target.
> 6. There should be no spin on the ball during its flight.
> 7. The ball should be released in front of the head.
> 8. Feet should remain on the ground.

Descriptive and prescriptive KP. After determining which aspect of the skill about which to give KP, the practitioner needs to decide the content of the statement to make to the learner. There are *two types of verbal KP statements.* A **descriptive KP** statement simply describes the error the performer has made. The other type, **prescriptive KP,** not only identifies the error, but also tells the person what to do to correct it. For example, if you tell a person, "You moved your right foot too soon," you describe only the problem. However, if you say, "You need to move your right foot at the same time as you move your right arm," you also give prescriptive information about what the person needs to do to correct the problem.

Which type of verbal KP better facilitates learning? The answer is that it varies with the stage of learning of the person practicing the skill. For example, the descriptive KP statement, "You moved your right foot too soon," would help a beginner only if he or she knew the actual time at which the right foot was supposed to move. Thus, descriptive KP statements are useful to help people improve performance only after they have learned what they need to do to make a correction. This suggests that *prescriptive KP statements are more helpful for beginners. For the more advanced performer, a descriptive KP statement often will suffice.*

Video Recordings as Augmented Feedback

The availability and use of video recordings as augmented feedback argues for the need for practitioners to know about how to use them effectively. It is common to find Internet sites and articles in professional journals that offer guidelines and suggestions for the use of video replays as feedback (e.g., Bertram, Marteniuk, & Guadagnoli, 2007; Franks &

> **descriptive KP** a verbal knowledge of performance (KP) statement that describes only the error a person has made during the performance of a skill.
>
> **prescriptive KP** a verbal knowledge of performance (KP) statement that describes errors made during the performance of a skill and states (i.e., prescribes) what needs to be done to correct them.

A CLOSER LOOK

Skilled Athletes Progress through Distinct Stages As They Learn to Use Video Replays

A study by Hebert, Landin, and Menickelli (1998) investigated the use of video replays as a part of the practice sessions for skilled female tennis players who needed to improve their attacking shots. Although the players who watched the video replays improved more than the players who did not, the athletes required a period of time to learn to use the replays effectively. According to the researchers' field notes and recordings of the athletes while they watched the videotapes, this period of time involved a progression through four stages in their use of the replays:

1. Players familiarized themselves with observing themselves on video. They made general comments about how they personally looked on videotape as well as about their playing techniques.
2. Players began to recognize specific technical errors in their attack shots.
3. Players became more analytical as they made direct connections between their technique and the outcome of that technique.
4. Players began to use their observations of replays to indicate corrections they should make to their technique errors. They indicated awareness of the key aspects of their performance that related to successfully hitting the attack shot.

Maile, 1991; Jambor & Weekes, 1995; Trinity & Annesi, 1996). However, very little empirical research exists that establishes the effectiveness of video replays as an aid for skill acquisition. In fact, the most recent extensive review of the research literature related to the use of video recordings as a source of augmented feedback in skill learning situations was published many years ago (Rothstein & Arnold, 1976). One likely reason why more recent reviews have not been published is that the research reported since that review has supported its general conclusions rather than establish different ones.

The most significant conclusion from that review was that the critical factor for determining the effectiveness of video replays as an instructional aid was the *skill level of the learner rather than the type of activity*. For beginners to benefit from video replays, they require the assistance of an instructor to point out critical information. Advanced performers do not appear to need instructor aid as frequently, although discussions with skilled athletes suggest they often receive greater benefit from observing replays when they receive some form of attention-directing instructions, such as verbal cues and checklists.

A good example of research that demonstrated the benefit of having an instructor point out what the observer of the video replay should look for was reported in an experiment that compared video replay as KP to verbal KP and no KP for teaching moderately skilled golfers to hit a golf ball for distance and accuracy (Guadagnoli, Holcomb, & Davis 2002). Three groups engaged in 90 min training sessions on each of four days: a control group, which the researchers called the "self-guided" group, practiced without any KP but could hit as many golf balls as they wanted; a verbal KP group received feedback from a PGA teaching professional throughout each session. The video KP group saw video replays of their swings throughout the sessions as well as getting the verbal KP from the teaching professional. The goal was to hit golf balls with a 7-iron as far as possible along a straight line. Performance was assessed by several distance and accuracy measures. Figure 15.4 shows the results for the "accuracy distance" measure, which was calculated by subtracting the distance a ball was off the straight target line from the total distance. This result, which is representative of the other measures, indicates the effectiveness of the video replay added to the verbal KP group for learning the golf swing: the video KP group performed better than the other two groups on a retention test given two weeks after the end of the training sessions (i.e., two-week

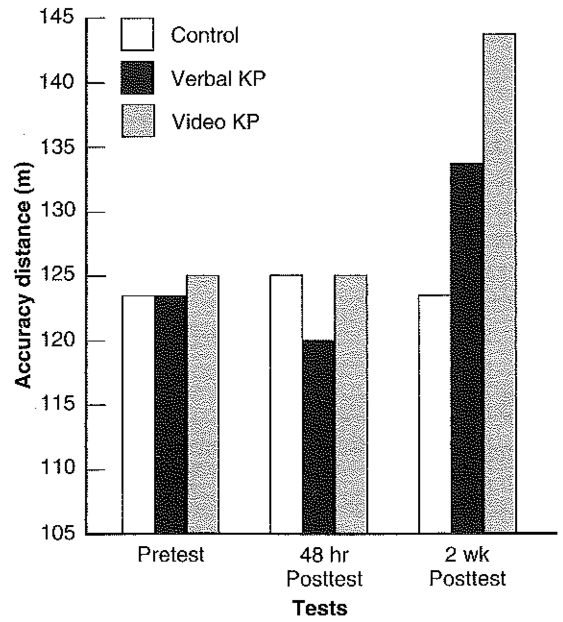


FIGURE 15.4 Results of the experiment by Guadagnoli et al. (2002) showing that video replays with verbal KP (video KP) led to better long-term retention performance than no KP (control) and verbal KP for learning to hit a golf ball for distance and accuracy. The performance measure "accuracy distance" is the total distance a ball traveled minus the distance from the target straight line. [Data from figure 2 (p. 990) in Guadagnoli, M., Holcomb, W., and Davis, M. (2002). The efficacy of video feedback for learning the golf swing. *Journal of Sports Sciences, 20,* 615–622.]

posttest). An interesting characteristic of this study demonstrates the importance of augmented feedback in relation to the amount of practice for learning of a skill. Because the golfers were not limited to hitting a specified number of balls during each training session, the three groups differed in the number of balls hit during training. Interestingly, the control group hit the most practice balls, but performed worse than the other two groups. The video KP group hit the fewest practice balls but learned the skill better than the other two groups.

Research evidence also establishes that video replays *transmit certain types of performance-related information more effectively than other types.* One of the best examples of an experiment that supports this conclusion was one conducted many years ago by Selder and Del Rolan (1979). They compared videotape replays and verbal augmented feedback (in the form of KP) in a study in which twelve-to-thirteen-year-old girls were learning to perform a balance beam routine. All the girls used a checklist to critically analyze their own performance after each trial. One group used verbal KP to complete the checklist; another group completed the checklist after viewing videotape replays of each trial. At the end of six weeks of practice, the videotape group scored significantly higher on the routine than the verbal KP group. More important, when each factor of the total routine score was evaluated, the videotape group scored significantly higher on only four of the eight factors: precision, execution, amplitude, and orientation and direction. The two groups did not differ on the other four: rhythm, elegance, coordination, and lightness of jumping and tumbling.

The results of this study suggest that video replay facilitates the learning of those performance features that performers can readily observe and determine how to correct on the basis of what they see on the video replay. However, for performance features that are difficult to visually discern, video replay is no more effective than verbal KP.

Movement Kinematics as Augmented Feedback

With the widespread availability of computer software capable of providing sophisticated kinematic analysis of movement, it has become increasingly common to find sport skill instruction and physical rehabilitation situations in which people can view graphically presented kinematic representations of their performances as a form of feedback. Unfortunately, as was the case with the use of video replays, there is little research evidence that provides definitive answers to questions concerning the effectiveness of this means of providing augmented feedback. However, the few studies that have been reported provide some insight into the use of this form of augmented feedback.

One of the first studies to investigate the use of movement kinematics did not involve a computer and was carried out many years ago. This study is important because it illustrates the historical interest in this type of feedback, it involved a real-world training situation, and it exemplifies the positive effect that kinematic information can have on skill learning. Lindahl (1945) investigated the methods used to train industrial machine operator trainees to precisely and quickly cut thin disks of tungsten with a machine that required fast, accurate, and rhythmic coordination of the hands and feet. The traditional approach to training for this job was a trial-and-error method. To assess an alternative method, Lindahl created a mechanism that would make a paper tracing of the machine operator's foot movement pattern during the cutting of each disk. During training, the trainers showed the trainees charts illustrating the correct foot action (see the top portion of figure 15.5), and periodically showed them tracings of their own foot action. The results (see the bottom portion of figure 15.5) indicated that this training method based on movement kinematic information as augmented feedback enabled the trainees to achieve production performance levels in eleven weeks, compared to the five months required by trainees who used the traditional trial-and-error method. In addition, the trainees reduced their percentage of broken cutting wheels to almost zero in twelve weeks, a level not achieved by those trained with the traditional method in less than nine months.

A comprehensive series of experiments reported by Swinnen and his colleagues serve as good examples of more recent laboratory research (Swinnen et al., 1990; Swinnen, Walter, Lee, & Serrien, 1993). Participants in these experiments practiced a bimanual coordination task that required them to simultaneously move two levers, but with each lever requiring a different spatial-temporal movement pattern. Kinematic information was presented as augmented feedback in the form of the angular displacement for each arm superimposed over the criterion displacements. In several experiments, the kinematic augmented feedback was compared with various other forms of augmented feedback. The results consistently demonstrated the effectiveness of the use of the displacement information.

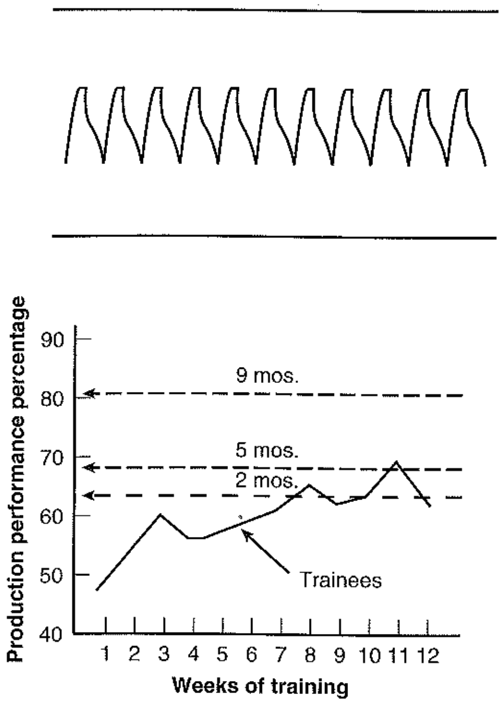


FIGURE 15.5 The upper panel illustrates the foot action required by the machine operator to produce an acceptable disk cut in the experiment by Lindahl. The graph at the bottom indicates the production performance achieved by the trainees using graphic information during twelve weeks of training. The dashed lines indicate the levels of performance achieved by other workers after two, five, and nine months of experience. [From Lindahl, L. G. (1945). Movement analysis as an industrial training method. *Journal of Applied Psychology, 29,* 420–436, American Psychological Association.]

An experiment by Wood, Gallagher, Martino, and Ross (1992) provides a good example of the use of graphically displayed movement kinematics for learning a sports skill. Participants practiced hitting a golf shot with a 5-iron. A commercially marketed golf computer monitored the velocity, displacement, and trajectory path of each swing as the head of the club passed over light sensors on the platform from which the ball was hit. This information was then displayed on a monitor. One group saw a template of an optimum pattern along with the kinematics; a second group did not see this template. A third group received the same kinematic information verbally in the form of numbers. A fourth group received no augmented feedback. On a retention test given one week later without augmented feedback, the group that had observed the graphic presentation of the swing kinematics along with the optimum pattern template performed best.

A CLOSER LOOK

A Case Study of the Use of Center of Gravity as Augmented Feedback for Balance Training for Stroke Patients

A form of augmented feedback that has been used for balance training in physical therapy contexts is the visual presentation on a computer monitor of a person's center of gravity. A case study reported by Simmons and associates (1998) is an interesting example of the effectiveness of this type of augmented feedback in a clinical setting.

The patient: A seventy-four-year-old poststroke, hemiparetic male with whom therapists were working to help him regain balance control while standing.

Balance training therapy: Following a pretest, the patient engaged in three balance training therapy sessions a week for four weeks. During each therapy session the patient stood on two force plates while looking at a computer monitor placed at eye level. On the monitor, he could see a small white dot superimposed on a white cross, which indicated an appropriate center of gravity while standing. During each therapy session, a clear plastic template marked with a circular pattern of eight alphabetic letters was placed on the monitor. A verbal command to the patient indicated that he should initiate a weight shift that would cause the white dot to move from the center and hit the target letter and then return the dot back to the center cross. The patient did this for six 1 min intervals with a 45 sec rest between intervals. A posttest followed at the end of the 4 wk training period, and a retention test was given two weeks later.

Results: One of the tests simulated a sudden loss of balance, which involved a quick (400 msec) 5.7 cm forward and backward movement of the force plates on which the patient was standing. The patient's performance on this motor control test during the 2 wk retention test showed a 60 percent improvement for response strength of the affected leg, and a marked shift in balance onto the affected leg in the patient's attempts to regain balance.

Another type of kinematic related information that has been effectively used as augmented feedback is a person's *center of pressure (COP).* This biomechanical type of information is most commonly used as a type of augmented feedback for people learning or improving static and dynamic balance skills. For example, a study by Taube, Leukel, and Gollhofer (2008) investigated the use of a handheld laser pointed at a target on a wall to provide augmented visual feedback of each participant's COP to assist them in maintaining upright standing balance on both rigid and unstable surfaces. Results showed that participants maintained better balance stability when they used the laser pointer device than when they did not.

Biofeedback as Augmented Feedback

The term **biofeedback** refers to an augmented form of task-intrinsic feedback related to the activity of physiological processes, such as heart rate, blood pressure, muscle activity, and the like. Several forms of biofeedback have been used in motor skill learning situations. The most common is *electromyographic (EMG) biofeedback,* which provides information about muscle activity.

EMG biofeedback has been commonly used in physical rehabilitation settings and research. Although researchers continue to debate its effectiveness there is general agreement that it can benefit motor skill learning. (For a review and critical

biofeedback a type of augmented feedback that provides information about physiological processes through the use of instrumentation (e.g., EMG biofeedback).

analysis of the use of EMG biofeedback in physical therapy see Huang, Wolf, & He, 2006). The following two research examples illustrate some of the positive results researchers have reported for the use of EMG as a source of augmented feedback. An experiment by Brucker and Bulaeva (1996) used EMG biofeedback with long-term cervical spinal cord–injured people to determine if it would help them increase their voluntary EMG responses from the triceps during elbow extension. Results indicated that participants who experienced only one 45 min treatment session significantly increased their triceps EMG activity; and those who experienced additional treatment sessions demonstrated even further increases.

The purpose of a study by Intiso and colleagues (1994) was to determine the effectiveness of EMG biofeedback to help poststroke patients overcome foot drop of the paretic limb during the swing phase of walking. Some patients received EMG biofeedback during their physical therapy, whereas others did not. A unique characteristic of this study was the use of gait analysis to assess foot drop during the gait cycle. Results of this analysis demonstrated that the EMG biofeedback intervention led to better recovery than physical therapy without the biofeedback.

A unique type of biofeedback was used by Chollet, Micallef, and Rabischong (1988) for swimmers. The researchers developed swimming paddles that would provide information to enable highly skilled swimmers to maintain their optimal velocity and number of arm cycles in a training session. The swimming paddles contained force sensors and sound generators that transmitted an audible signal to transmitters in a swimmer's cap. The sensors were set at a desired water-propulsion-force threshold; when the swimmer reached this threshold, the paddles produced a sound audible to the swimmer. The results showed that this device helped swimmers maintain their stroke count and swimming speed when they otherwise would have found it decreasing through the course of a long-distance practice session.

Finally, another type of biofeedback has been applied in the training of competitive rifle shooters (Daniels & Landers, 1981). Heartbeat biofeedback was presented audibly to help these athletes learn to squeeze the rifle trigger between heartbeats, which is a characteristic of elite shooters.

In general, research evidence has supported the effectiveness of biofeedback as a means of facilitating motor skill learning. However, debate continues concerning the specific situations in which the use of biofeedback is an effective and preferred form of augmented feedback, especially in physical rehabilitation situations (e.g., Moreland & Thomson, 1994; Moreland, Thomson, & Fuoco, 1998).

An additional concern about the use of biofeedback as augmented feedback is the tendency for people to become dependent on it to help them perform the skill. The result of this dependency is that when they must perform the skill without biofeedback, their performance level decreases. This concern is not unique to the use of biofeedback but to all types of augmented feedback. We will address this issue, along with strategies to overcome the problem, in the last section of this chapter in which the frequency of presenting augmented feedback will be discussed.

TIMING ISSUES RELATED TO AUGMENTED FEEDBACK

Finally, three important questions arise about the timing of giving augmented feedback. To continue with the example in which you are teaching a person to play golf, one question is this: Should you give augmented feedback while the person swings, after he or she has hit the ball, or both times? If you give feedback after the person hits the ball, the second question arises: How soon after the person's hitting of the ball should you give augmented feedback? The third question concerns whether you should give augmented feedback every time the person hits the ball, or only a few times during the practice session.

Concurrent and Terminal Augmented Feedback

Is it better to give augmented feedback while a person is performing a skill, in what is known as **concurrent augmented feedback** or at the end of a practice attempt, in what we call **terminal augmented feedback?** Unfortunately, a search through the motor learning research literature suggests that there is no unequivocal answer to this question. However, a guideline emerges from that literature that can help us answer the question. Terminal augmented feedback can be effective in almost any skill learning situation, although the teacher or therapist must consider the nature of its effect in light of our discussion earlier in this chapter of the four different effects augmented feedback can have on skill learning. Concurrent augmented feedback, as you will see in the following sections of this discussion, seems to be most effective when the task-intrinsic feedback is difficult to use to determine how to perform the skill or improve performance. Because most of the discussion thus far in this chapter has involved terminal augmented feedback, the focus of this section will be on concurrent augmented feedback.

Effects of concurrent augmented feedback on learning. Research evidence has shown two general types of effects for the use of concurrent augmented feedback in skill learning situations. The more common is *a negative learning effect.* Although performance improves very well during practice when the feedback is available, it declines on retention or transfer trials during which the augmented feedback is removed. In these situations, the concurrent augmented feedback influences learners to direct their attention away from the critical task-intrinsic feedback and toward the augmented feedback. The result is that they substitute the information derived from augmented feedback for the important information they should acquire from task-intrinsic feedback. The result is that the augmented feedback becomes an integral part of what is learned, and therefore necessary for future performance.

Two experiments, one involving a continuous skill and the other involving a discrete skill, provide examples of research that has demonstrated this negative learning effect. Verschueren, Swinnen, Dom, and DeWeerdt (1997) had elderly healthy adults and Parkinson's patients practice the continuous bimanual coordination task described in chapters 11 and 12 (see figure 11.4). The task required that they learn to move two levers simultaneously for 20 sec in such a way that they would draw ellipses

A CLOSER LOOK

Concurrent Augmented Feedback Can Take Various Forms

When augmented feedback is given concurrently, it typically enhances task-intrinsic feedback while a person is performing a skill. The following examples illustrate the various forms that this enhancement can take.

Activity Characteristic	Activity Example	Concurrent Augmented Feedback
Continuous movement accuracy	Steering in a car simulator through a narrow, winding street	Continuous visible or audible signal when vehicle is inside or outside the street boundaries
Move a specific amount of distance for a period of time	Knee-extension device that measures range of motion	Continuous curve on computer monitor showing knee angle
Activate specific muscle	Walking	Continuous audible signal when the target muscle is activated

concurrent augmented feedback augmented feedback that is provided while a person is performing a skill or making a movement.

terminal augmented feedback augmented feedback that is provided after a person has completed the performance of a skill or a movement.

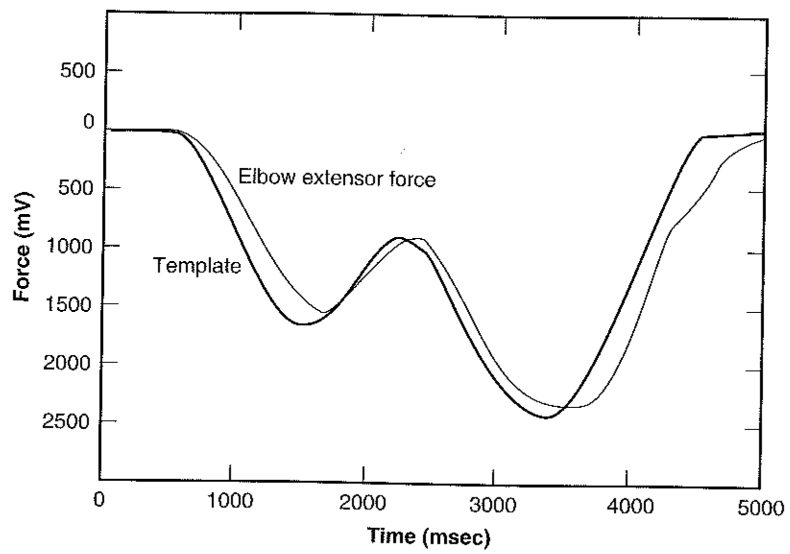


FIGURE 15.6 An example from the Vander Linden et al. experiment of what a participant saw during and/or after a trial on which they attempted to produce a 5 sec elbow-extension force trace that replicated as closely as possible the template trace. [Reprinted from Vander Linden, D. W. et al. (1993). "The effect of frequency of kinetic feedback on learning an isometric force production task in non-disabled subjects," *Physical Therapy, 73,* 79–87 with permission of the American Physical Therapy Association.]

on the computer monitor. During the practice trials, participants saw on the monitor the drawings produced as they moved their arms. The results showed that participants in both groups made considerable improvement during practice when the concurrent visual augmented feedback was available. But their performance dropped dramatically on retention test trials without the augmented feedback.

The negative learning effect has also been demonstrated for the learning of a discrete task. Vander Linden, Cauraugh, and Greene (1993) compared concurrent and terminal augmented feedback for learning a 5 sec isometric elbow-extension force production task, which is illustrated in figure 15.6. Participants received augmented feedback by seeing the force produced during the performance of the task on each trial. One group received this feedback concurrently. Two other groups received this feedback after they completed performing the task. One of these two groups saw this information after every trial; the other saw it after every other trial. During the practice trials, the concurrent augmented feedback group performed the task better than the two terminal groups. However, forty-eight hours later on a retention test with no augmented feedback, the concurrent group's performance declined to a level that was the poorest of the three groups.

The second general effect is that concurrent augmented feedback *enhances skill learning.* A variety of situations have produced this effect. Some of these are the training of flight skills for airplane pilots (e.g., Lintern, 1991), the rehabilitation of motor skills in physical therapy (e.g., Intiso et al., 1994), the activation of specific muscles or muscle groups (e.g., Brucker & Bulaeva, 1996), and the learning of certain types of bimanual coordination laboratory tasks (e.g., Swinnen et al., 1993). In these experiments, concurrent augmented feedback enhanced relevant features of the task-intrinsic feedback that were difficult to discern without the enhancement. Because most of these experiments are described elsewhere in this book, there is no need to describe them here.

Predicting learning effects of concurrent augmented feedback. Two related hypotheses have been proposed to help us better understand how to predict when concurrent augmented feedback will have a positive or negative effect on learning. First, Annett (1959, 1969, 1970) stated that augmented feedback should be considered in terms of its information value, which he related to the "informativeness" of the task-intrinsic feedback and the augmented feedback. When the information value

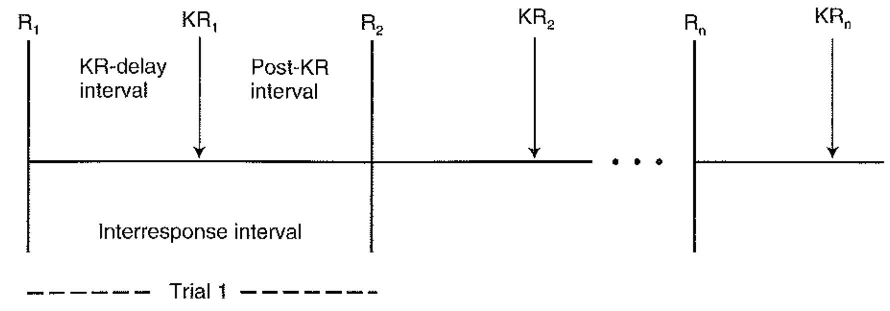


FIGURE 15.7 Intervals of time related to KR during the acquisition of a skill.

of task-intrinsic feedback is low, but the information value of the augmented feedback is high, concurrent augmented feedback will most likely lead to a dependency on the augmented feedback.

Lintern and his colleagues (Lintern, 1991; Lintern, Roscoe, & Sivier, 1990) added another dimension to Annett's hypothesis by proposing that practicing with augmented feedback will benefit learning to the extent that the feedback sensitizes the learner to properties or relationships in the task that specify how the system being learned can be controlled. This means that *for concurrent augmented feedback to be effective, it must facilitate the learning of the critical characteristics or relationships in the task as specified by the task-intrinsic feedback.* Negative learning effects will result when the augmented feedback distracts attention away from these features. But positive learning effects will result when the augmented feedback directs attention to these features.

THE KR-DELAY AND POST-KR INTERVALS

The second timing issue related to augmented feedback concerns when the feedback is given terminally. Two intervals of time are created between two trials: the **KR-delay interval** and the **post-KR interval.**[1] These intervals are depicted graphically in figure 15.7. To understand the relationship between these intervals and skill learning, we must understand the influence of two variables: *time,* or the length of the interval, and *activity,* or the cognitive and/or motor activity during the interval.

The Length of the KR-Delay Interval

It is not uncommon to see statements in textbooks indicating that a learner should receive augmented feedback as soon as possible after performing a skill, because delaying it beyond a certain amount of time would lead to poorer learning. A significant problem with this viewpoint is that it has little research evidence to support it. Such a view comes from research based predominantly on animal learning (see Adams, 1987). Research has established that humans use augmented feedback as more than a reward: augmented feedback has informational value that humans use to solve problems associated with learning a skill. Whereas animal learning studies have shown that delaying reward leads to decreased learning, human skill learning studies have shown that delaying augmented feedback does not have this negative effect.

KR-delay interval the interval of time between the completion of a movement and the presentation of augmented feedback.

post-KR interval the interval of time between the presentation of augmented feedback and the beginning of the next trial.

[1]Note that the terminology used to describe these two intervals follows the traditional labels used in the majority of the research literature, even though we have been using the term KR in a more specific way than these interval labels imply. It is important to see these intervals as relevant to *all* forms of augmented feedback.

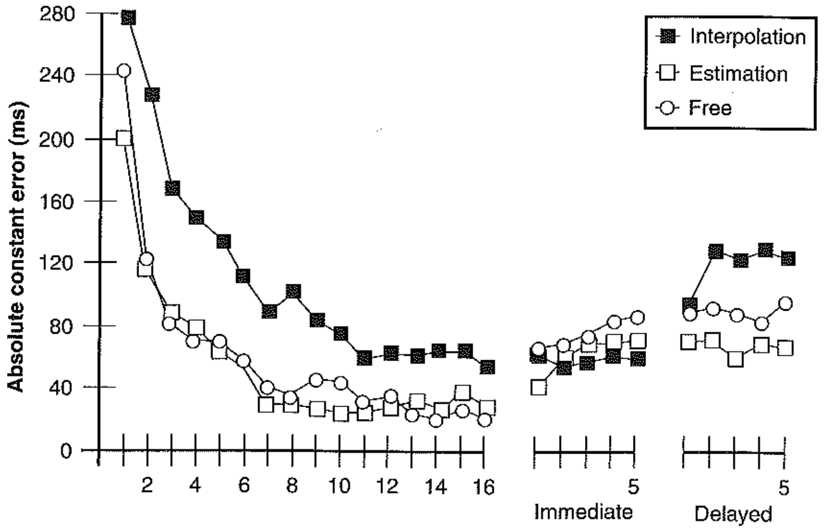


FIGURE 15.8 Results from the experiment by Swinnen showing the influence of estimating the experimenter's movement error (interpolation group) and the influence of estimating the participant's own error (estimation group) during the KR-delay interval, compared with no activity during the interval (free group). [From Swinnen, S. P. (1990). Interpolated activities during the knowledge of results delay and post-knowledge of results interval: Effects on performance and learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 692–705. Copyright © 1990 by the American Psychological Association. Reprinted with permission.]

Activity During the KR-Delay Interval

Researchers investigating the effects of activity during the KR-delay interval have found *three types of outcomes.* The most common effect of activity during the KR-delay interval on skill learning is that it has *no influence on learning.* Experiments have demonstrated this result since the 1960s (e.g., Bilodeau, 1969; Boulter, 1964; Marteniuk, 1986).

The second type of effect is much less common. There is some evidence, although it is sparse, that activity during the KR-delay interval *hinders learning.* Two specific types of activities have shown this negative effect. One type includes activities that involve the same learning processes required by the primary task being learned. For example, Marteniuk (1986) showed that when another motor or cognitive skill had to be learned during the KR-delay interval, these activities interfered with learning of the primary skill. The other type of activity that research has shown to hinder skill learning involved estimating the movement-time error of another person's movement, which the second person performed during the interval. In an experiment by Swinnen (1990), people learned to move a lever a specified distance, involving two reversals of direction, in a criterion movement time. Participants who engaged in the error estimation activity during the KR-delay interval showed worse performance on a retention test than those who did nothing or who performed a non-learning task during the interval.

Subjective performance evaluation. The third type of effect is that certain activities during the KR-delay interval actually can *benefit learning.* One type of activity that has consistently demonstrated this effect requires the person to evaluate his or her own performance. We will refer to this activity as the *subjective performance evaluation strategy.* Research has established the effectiveness of two approaches to the use of this strategy. One requires the estimation of the outcome of the performance, the other requires the estimation of the movement-related characteristics of the performance of the skill. Swinnen (1990), in the experiment described above, compared the strategies of the participant estimating his or her own performance outcome error with estimating performance outcome error of another person's movement. Figure 15.8 shows that subjective performance estimation led to a learning benefit, but estimating another person's performance hindered learning. More recently, Sherwood (2008) further established the learning benefit of the subjective performance error strategy in an experiment

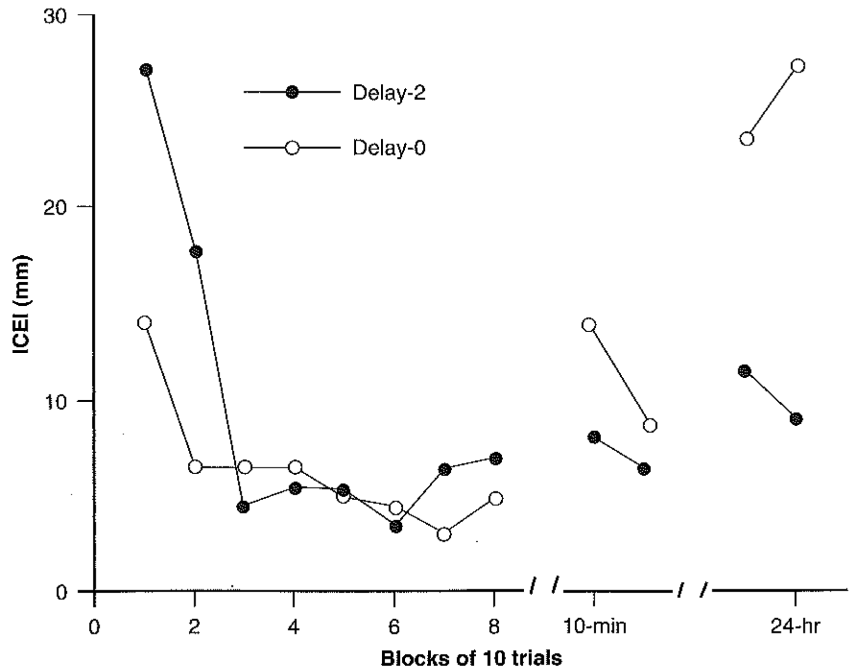


FIGURE 15.9 Results of the Anderson et al. experiment showing the beneficial effects of delaying a trial's KR for two trials (delay-2) compared to presenting KR after each trial (delay-0) for learning a manual aiming task. [Reprinted with permission from *Research Quarterly for Exercise and Sport, Vol. 65, No. 3,* 286–290. Copyright © 1994 by the American Association for Health, Physical Education, Recreation, and Dance, 1900 Association Drive, Reston, VA 20191.]

involving four different laboratory learning tasks, in which participants estimated their own error on each trial prior to receiving KR.

The second type of beneficial subjective performance estimation involves the estimation of specific characteristics of some of the movement-related components of an action. In an experiment by Liu and Wrisberg (1997) participants practiced throwing a ball at a target as accurately as possible with the nonpreferred arm and without vision of the target. Participants received KR by seeing where on the target the ball had landed on each trial. During the KR-delay interval, some of the participants rated on 5-point scales the appropriateness of the force, angle of ball release, and ball trajectory of the throw, and then estimated the throw's point value on the target. The results indicated that these participants performed more accurately on a retention than those who had not used the estimation strategy.

We find an interesting parallel to the subjective performance evaluation strategy in what researchers call the *trials-delay procedure.* Here, experiment participants receive KR for a trial after they complete performance on a later trial. Anderson, Magill, and Sekiya (1994) reported one of the most recent experiments providing evidence for the effectiveness of this effect. Participants practiced making a blindfolded aiming movement. One group received KR about distance error after every trial (delay–0). A second group received KR two trials later (delay–2), which meant that they were told their error for trial 1 after completing trial 3. Results (figure 15.9) were that while the delay condition hindered performance during practice, it led to better performance on a twenty-four-hour retention test.

Learning processes. What do these different effects of activity reveal about learning processes that occur during the KR-delay interval? During this time interval, the learner is actively engaged in learning processes involving activities such as developing an understanding of the task-instrinsic feedback and establishing essential error detection capabilities.

For instructional purposes, the most significant implication of the effects of activity during the

KR-delay interval is that people who are practicing a skill can use a beneficial strategy after they complete the performance of a skill and before they receive augmented feedback. That is, they could verbally describe what they think they did wrong that led to a less than desired performance outcome.

The Length of the Post-KR Interval

The significance of the post-KR interval is that it is during this period of time that the learner develops a plan of action for the next trial. This planning occurs during this interval because the learner now has available both task-intrinsic feedback and augmented feedback.

If the learner processes critical skill learning information during the post-KR interval, we would expect there to be a minimum length for this interval. Although there is not an abundance of research that has investigated this issue, there is empirical evidence from many years ago that provided evidence that indeed, this interval can be too short (e.g., Weinberg, Guy, & Tupper, 1964; Rogers, 1974; Gallagher & Thomas, 1980). For optimal learning, a minimum amount of time is needed for the learner to engage in the learning processes required. Conversely, there is no evidence indicating an optimal length for the post-KR interval. Research consistently has shown no apparent upper limit for the length of this interval.

Activity during the Post-KR Interval

The effect of engaging in activity is similar for the post-KR interval to that for the KR-delay interval. Depending on the type of activity, activity can have no effect on learning, interfere with learning, or benefit learning.

The most common finding has been that activity during the post-KR interval *has no effect on skill learning*. The best example is in an experiment by Lee and Magill (1983) in which participants practiced making an arm movement in 1,050 msec. During each post-KR interval, one group attempted the same movement in 1,350 msec, one group engaged in a cognitive activity involving number

LAB LINKS

Lab 15b in the Online Learning Center Lab Manual provides an opportunity for you to experience the effects on motor skill learning of estimating your own error during the KR-delay interval during practice.

guessing, and a third group did no activity. At the end of the practice trials, the two activity groups showed poorer performance than the no-activity group. However, this was a temporary performance effect rather than a learning effect: on a no-KR retention test, the three groups did not differ.

Several researchers have reported results indicating that activity during the post-KR interval *hinders learning*. Of these, only those by Benedetti and McCullagh (1987) and Swinnen (1990, experiment 3) included appropriate tests for learning. In both of these experiments, the interfering activity was a cognitive activity. Participants in the experiment by Benedetti and McCullagh engaged in a mathematics problem-solving task, whereas those in the experiment by Swinnen guessed the movement-time error of a lever movement the experimenter made during the post-KR interval.

Only one experiment (Magill, 1988) has demonstrated that *beneficial learning effects* can result from activity in the post-KR interval. Participants learned a two-component arm movement in which each component had its own criterion movement time. During the post-KR interval, one group had to learn two additional two-component movements, one group had to learn a mirror-tracing task, and a third group did not engage in activity. Results showed that the two groups that engaged in activity during the post-KR interval performed better than the no-activity group on a transfer test in which they learned a new two-component movement.

What do these different effects of activity tell us about learning processes that occur during the post-KR interval? They support the view we discussed earlier that learners engage in important planning activities during this time period. They use this

planning time to take into account the discrepancy between the task-intrinsic and the augmented feedback, to determine how to execute the next attempt at performing the skill. Much of this planning seems to require cognitive activity; we see this in the experiments showing that engaging in attention-demanding cognitive problem-solving activity during this interval hinders learning.

FREQUENCY OF PRESENTING AUGMENTED FEEDBACK

For many years, the view was that augmented feedback should be given during or after every practice trial (i.e., 100 percent frequency), because no learning occurred on trials without augmented feedback. However, beginning with the influential review and evaluation of the KR literature by Salmoni, Schmidt, and Walter (1984) and continuing to the present time, this traditional view has been revised as researchers have provided evidence that is contrary to predictions of that viewpoint.

The Reduced Frequency Benefit

Sufficient research evidence has now accumulated for us to say confidently that the *optimal frequency for giving augmented feedback is not 100 percent*. The most influential evidence to support this conclusion was an experiment by Winstein and Schmidt (1990). They had participants practice producing the complex movement pattern shown in the top panel of figure 15.10 by moving a lever on a tabletop to manipulate a cursor on a computer monitor. During the two days of practice, participants received KR after either 100 percent or 50 percent of the trials. For the 50 percent condition, the experimenters used a *fading technique* in which they systematically reduced the KR frequency; they provided KR after each of the first twenty-two trials of each day, then had participants perform eight trials with no KR, then systematically reduced the frequency from eight to two trials for the remaining eight-trial blocks each day. The results of this experiment are presented in the bottom panel of figure 15.10. In a no-KR retention test given one

LAB LINKS

Lab 15c in the Online Learning Center Lab Manual provides an opportunity for you to compare the effects on motor skill learning of different frequencies of receiving KR during practice

day later, the faded 50 percent frequency condition led to better retention performance than the 100 percent condition produced. In fact, people who had received KR after every practice trial showed retention test performance at a level resembling that of their first day of practice.

The Winstein and Schmidt (1990) study has generated a great deal of research since it was published. The research has focused on two predominant themes: providing additional empirical support for the reduced frequency benefit, and determining whether or not an optimal frequency exists to enhance skill learning. Two interesting conclusions have resulted from these research efforts. First, although a reduced frequency of augmented feedback can benefit motor skill learning, it may *not* benefit the learning of all motor skills. Second, an optimal relative frequency appears to be specific to the skill being learned.

Theoretical Implications of the Frequency Effect

The challenge for those interested in developing motor learning theory is to establish why giving augmented feedback less than 100 percent of the time during practice is better for skill learning. One possible reason is that when people receive augmented feedback after every trial, they eventually experience an attention-capacity "overload." After several trials, the cumulative effect is that there is more information available than the person can handle.

A more likely possibility is that giving augmented feedback on every trial leads to engaging the learner in a fundamentally different type of learning processing than he or she would experience if it were not given on every trial. Schmidt and his colleagues (e.g., Salmoni, Schmidt, & Walter, 1984; Winstein & Schmidt, 1990) proposed

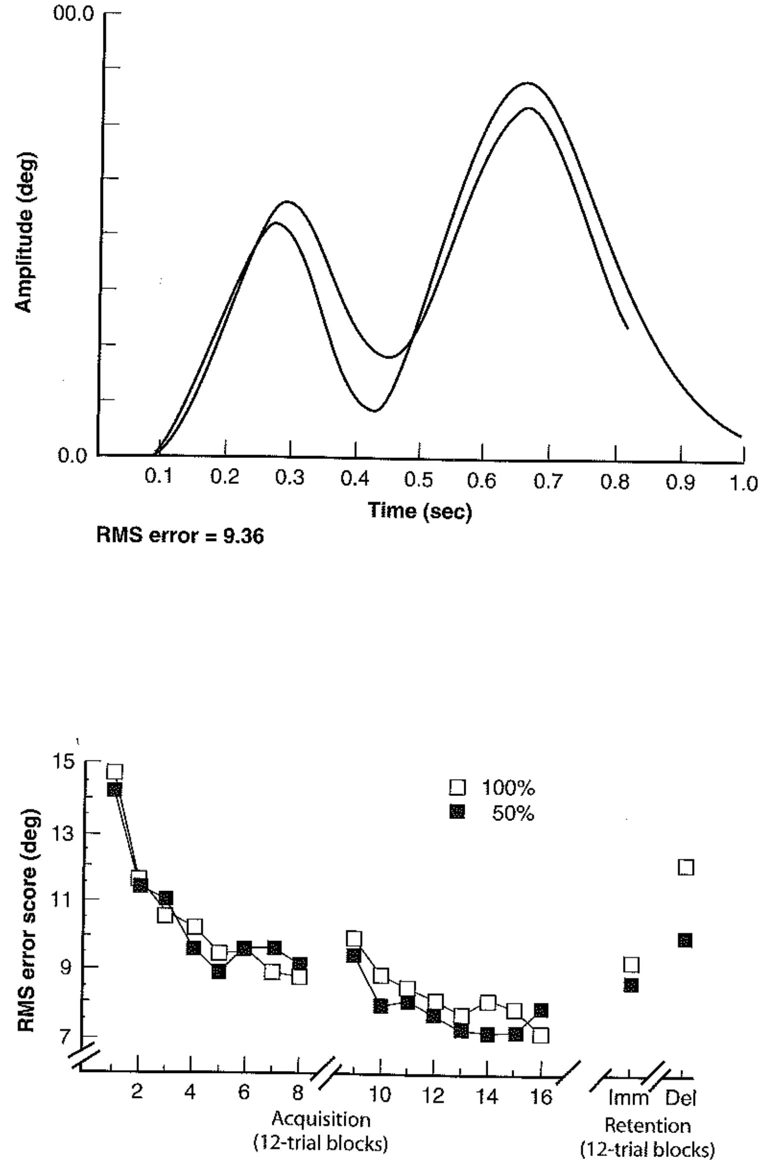


FIGURE 15.10 The top panel shows the goal movement pattern in the Winstein and Schmidt experiment. A sample of one participant's attempt to produce this pattern is superimposed. The RMS error score is shown as the subject saw it. Note that the goal pattern lasted for 0.8 sec while the participant produced a 1.0 sec pattern. The bottom panel shows the results of this experiment for the 100 percent KR frequency and 50 percent KR frequency groups, where the 50 percent group had KR frequency "faded" from 100 percent to 0 percent. [From Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 677–691. Copyright © 1990 American Psychological Association. Reprinted by permission.]

this view, which they called the **guidance hypothesis.** According to this hypothesis, if the learner receives augmented feedback on every trial (i.e., at 100 percent frequency), then it will effectively "guide" the learner to perform the movement correctly. However, there is a negative aspect to this guidance process. By using augmented feedback as the guidance source, the learner develops a dependency on the availability of augmented feedback so that when he or she must perform the skill without it, performance will be poorer than if augmented feedback were provided. In effect, augmented feedback becomes a crutch for the learner that is essential for performing the skill.

The hypothesis further proposes that receiving augmented feedback less frequently during practice

encourages the learner to engage in more beneficial learning strategies during practice. For example, active cognitive and movement problem-solving activities increase during trials with no augmented feedback. The learner does not become dependent on the availability of augmented feedback and therefore can perform the skill well, even in its absence. (For an extensive review of research investigating the guidance hypothesis and an experiment that provides support for it, see Maslovat, Brunke, Chua, & Franks, 2009).

TECHNIQUES THAT REDUCE AUGMENTED FEEDBACK FREQUENCY

Now that we have established that it is generally more effective to provide augmented feedback less frequently than on every practice trial, a question that remains concerns how to implement ways that reduce frequency. The fading technique, described in the previous section, is one useful approach to reducing frequency. But several other techniques are effective as well.

Performance-Based Bandwidths

Earlier in this chapter we discussed a strategy for presenting augmented feedback that involved providing it only when a person's performance error was larger than a predetermined amount. We referred to this strategy as giving augmented feedback according to *performance-based bandwidths.* If we relate this bandwidth technique to the augmented feedback frequency issue, we can see how the bandwidth technique influences the frequency of presenting augmented feedback.

Lee, White, and Carnahan (1990) were the first to investigate this relationship. In their experiment they paired individual participants so that one of each pair received KR only on the trials on which the other of the pair received KR in 5 percent and 10 percent bandwidth conditions. The reason for the pairing of participants (a procedure known as "yoking") was to control for the possibility that the performance-based bandwidth benefit for learning was due to a reduced KR frequency. Thus, KR frequency was the same for each pair of participants, but the KR frequency for the participant in the bandwidth condition depended on the 5 and 10 percent criteria. Results showed that the bandwidth-based KR conditions led to better retention performance. The researchers concluded that the performance-based bandwidth technique reduces augmented feedback frequency, which is an important reason why the technique enhances learning.

Two additional experiments will serve as examples of research that provide support for the learning benefit derived from the relationship between the performance-based bandwidth technique and augmented feedback frequency. Goodwin and Meeuwsen (1995) compared 0 percent and 10 percent error bandwidth conditions with those that were systematically expanded (0-5-10-15-20 percent) and contracted (20-15-10-5-0 percent) for learning to putt a golf ball a criterion distance. The two conditions that resulted in the best retention test performance showed interesting KR frequencies. The frequencies for the 10 percent bandwidth condition reduced from 62 percent during the first twenty trials, to between 47 percent and 50 percent on the remaining trials. For the expanding bandwidth condition, KR frequencies began at 99 percent for the first twenty trials when the bandwidth was 0 percent, but then eventually reduced to 19 percent by the end of the practice trials, as the bandwidths increased in size. Lai and Shea (1999) reported similar findings for the learning of a complex spatial-temporal movement pattern. These results indicate that for the performance-based bandwidth technique it is the reduction of KR frequency during practice that is important to improved learning.

From an instructional perspective, the bandwidth technique provides a useful means of

guidance hypothesis a hypothesis indicating that the role of augmented feedback in learning is to guide performance to be correct during practice; however, if it is provided too frequently, it can cause the learner to develop a dependency on its availability and therefore to perform poorly when it is not available.

A CLOSER LOOK

When Reduced Frequency of KR is Not Beneficial: Learning with Proprioception Deficits

Parkinson's disease (PD) is characterized by basal ganglia dysfunction. As a result, people with PD have a compromised proprioceptive feedback system that often leads to their having difficulty with the timing control of movements and integrating sensory and motor information. Because of this deficit, it would be expected that people with PD would benefit from KR as an external source of performance information to make the types of movement corrections needed to learn a motor skill that requires precise timing of an arm movement. An experiment reported by Guadagnogli, Leis, Van Gemmert, and Stelmach (2002) tested this hypothesis by comparing PD patients with normal age-matched individuals on the effect of different frequencies of KR for learning a motor skill.

Participants: Twenty PD patients (avg. age = 65.2 years); Twenty normal age-matched adults

Task: Make an arm-pointing movement as close as possible to a goal movement time (based on 65 percent of a participant's maximum speed). The movement began at a home position on a tabletop in front of the participant and moved to a target located behind a barrier that required the arm to initially move to the right to avoid the barrier and then to the left to the target. The minimum distance possible was 39 cm.

Practice and test: Sixty practice trials followed by 10 min of general conversation (i.e., a "filled" retention interval) followed by a fifteen-trial no-KR retention test.

KR conditions: KR was displayed on a computer monitor as the percentage too fast or too slow of the goal movement time (presented on a computer monitor); for example, if goal movement time was 2,000 msec, and movement was 2,400 msec, KR was displayed as "20% too fast."

One-half of PD patients and control participants received KR on

- 100 percent of the practice trials
- 20 percent of the practice trials

Results:

End of practice: Absolute error (AE) and variable error (VE) scores did not differ between the two KR frequencies, although the PD patients had higher amounts of error than the controls.

No-KR retention test: The PD patients with 20 percent KR frequency during practice had higher AE and VE scores than those with 100 percent KR frequency. The control participants with 100 percent KR frequency during practice had higher AE and VE scores than those with 20 percent KR frequency.

Conclusion: Consistent with research with healthy adults, KR presented on 100 percent of the practice trials led to poorer learning of the arm movement skill than when KR was presented on only 20 percent of the practice. However, the opposite result was found for the PD patients. As hypothesized, to learn the movement timing skill, the PD patients depended on KR during practice as an external source of information to provide movement time feedback that they could not interpret through their own proprioceptive feedback system or integrate with the motor system.

individualizing the systematic reduction of the frequency of augmented feedback in practice situations. The bandwidth technique gives the practitioner a specific guideline for when to provide augmented feedback that encourages the learner to engage in important learning strategies. And because the bandwidth is related to individual performance, the learner can engage in these strategies at his or her own rate.

Self-Selected Frequency

Another technique that bases the frequency of augmented feedback on the individual involves the learner *receiving augmented feedback only when he or she asks for it.* The learning benefits derived from this approach appear to result from the learner participating more actively in determining characteristics of the practice conditions by self-regulating the presentation of augmented feedback. An experiment by Janelle, Kim, and Singer (1995) provided initial evidence that this strategy can enhance the learning of motor skills. College students practiced an underhand golf ball toss to a target on the ground. The students received KP about ball force, ball loft, and arm swing during practice. Compared to groups that received KP according to experimenter-determined frequencies (all of which received it less frequently than on every trial), the participants who controlled KP frequency themselves performed more accurately on the retention test.

Janelle substantiated and extended these results in a later study in which videotape replay was a source of augmented feedback in addition to verbal KP (Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997). Participants in the self-regulated group controlled the augmented feedback schedule by requesting KP at will during 200 practice trials. An important characteristic of this experiment was that individual participants in another group were paired (i.e., yoked) to participants in the self-regulated condition to receive KP on the same trials, but without requesting it. The importance of this yoked condition was to control for the possibility that the effect of self-regulation of augmented feedback is due only to reduced frequency. Results showed that participants in the self-regulated condition learned the throwing accuracy task with more accuracy and better throwing technique than participants in the other KP and yoked conditions.

In terms of augmented feedback frequency, it is interesting to note that participants in the self-controlled condition requested KP on only 7 percent of the practice trials in the Janelle et al. (1995) experiment, and on only 11 percent in the Janelle et al. (1997) experiment. These low frequencies indicate that there is some relationship between the self-controlled procedure and the reduced relative frequency of augmented feedback. However, because people in the self-controlled conditions in both experiments performed better on retention tests than those in the frequency-yoked conditions, the benefit of the self-controlled situation is more than a simple frequency effect.

Why do beginners ask for feedback from an instructor? An experiment by Chiviakowsky and

Wulf (2002) asked this question to participants in an experiment involving the learning of a sequential timing task. Each participant was asked on a questionnaire, "When/why did you ask for feedback?" Two-thirds of the participants answered that it was after what they considered to be a good trial (i.e., a trial during which they thought their performance was relatively successful). None indicated they asked for feedback after what they thought was a bad trial. Similar findings have been reported by these researchers in two additional experiments (Chiviakowsky & Wulf, 2005, 2007).

Research showing that learning is enhanced when learners can select when they want augmented feedback, and the fact that this selection typically occurs after trials that are thought to be relatively successful, provides interesting insight into the role of augmented feedback in skill learning. In general these results indicate the importance of augmented feedback as a source of information to confirm a learner's subjective evaluation of his or her performance. Two points are especially relevant from these findings. *First*, the use of augmented feedback in this way allows beginners to engage in their own problem-solving strategies as they learn the skill. *Second*, these results provide excellent evidence that learners use augmented feedback as a source of motivation to continue to practice. When they perform a relatively successful trial they ask for augmented feedback to reinforce their own subjective evaluation of their performance, which encourages them to continue to practice the skill. (For a more in-depth discussion of why receiving augmented feedback after good trials benefits learning, see Chiviakowsky & Wulf, 2007).

Summary and Averaged Augmented Feedback

Another way to reduce the frequency of augmented feedback presentations is to give a listing of performance-related information after a certain number of practice trials. This technique, which is known as *summary augmented feedback,* reduces the presentation frequency of augmented feedback while providing the same amount of information as if it were given after every trial.

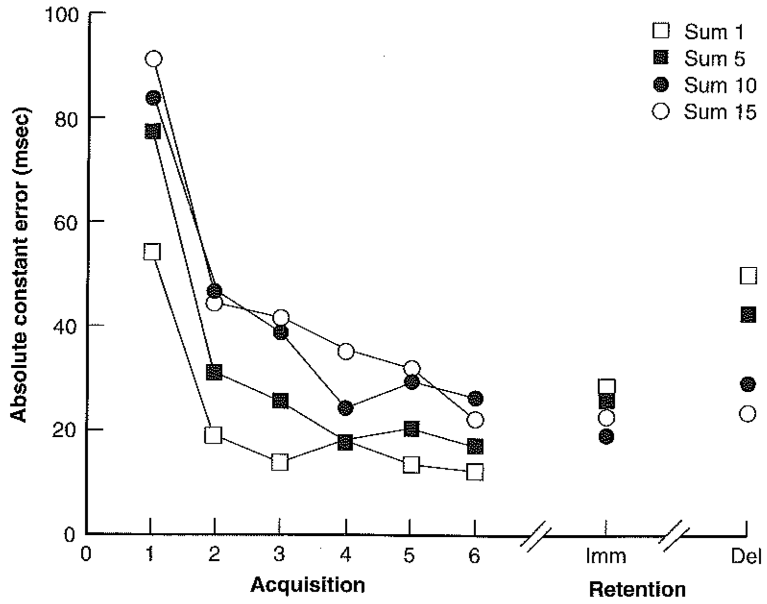


FIGURE 15.11 Results of the experiment by Schmidt et al., showing the effects of learning a timing movement with different summary KR conditions. (Sum 1 = KR after every trial; Sum 5 = KR for five trials presented every five trials, etc.) [From Schmidt, R. A., et al., (1989). Summary knowledge of results for skill acquisition: support for the guidance hypothesis. *Journal of Experimental Psychology: Learning, Memory and Cognition. 15,* 352–359. Copyright © 1989 American Psychological Association. Reprinted by permission.]

The summary technique could be advantageous in several types of skill learning situations. For example, suppose that a therapy patient must do a series of ten leg extensions in relatively rapid succession. To give augmented feedback after every extension may not be possible, if time limits restrict access to performance information after each attempt. A summary of all ten attempts could help overcome this limitation. Or suppose that a person is practicing a shooting skill for which he or she cannot see the target because of the distance involved. Efficiency of practice could be increased if that person did not receive augmented feedback after each shot, but received information about each shot after every ten shots.

The first study to generate a great deal of interest in the summary technique was a laboratory-based experiment by Schmidt, Young, Swinnen, and Shapiro (1989). The task involved moving a lever along a trackway to achieve a goal movement time. During the practice trials, participants received KR after every trial or in summary form after five, ten, or fifteen trials. The results of this experiment (see figure 15.11) showed very little difference between the conditions during practice and on a retention test given ten minutes after practice. But on a retention test two days later, the group that had received KR after every trial performed the worst, whereas the group that had received summary KR after every fifteen trials performed the best.

In an experiment involving the learning of target shooting with rifles, Boyce (1991) provided one group with KP after every shot, and another group with KP about every shot after each fifth shot. The results showed no difference in eventual shooting performance by these groups. Although the summary method did not yield better performance than the method giving KP after every shot, its effectiveness as an instructional technique was established, because it was just as effective for improving performance as the other method.

Numerous studies have provided evidence supporting the benefit of the summary technique for motor skill learning (e.g., Schmidt, Lange, & Young, 1990; Wright, Snowden, & Willoughby, 1990; Guay, Salmoni, & Lajoie, 1999; Herbert, Heiss, & Basso, 2008). However, a very practical question remains to be answered: What is the optimal number of performance attempts, or practice trials, to include in a summary augmented feedback statement? Although there have been several attempts to determine whether a specific number of trials is optimal, the results have been equivocal. Two answers appear reasonable at the present time on the basis of results of research that has investigated this question.

First, Sidaway, Moore, and Schoenfelder-Zohdi (1991) concluded that the positive effects of the summary technique are not due to the number of trials summarized, and stated that their results argue against the notion of an "optimal summary length." Instead, they argued that the summary effect is related either to the reduced frequency of presenting augmented feedback or to the trials delay involved in presenting augmented feedback using the summary technique (note that the summary technique has characteristics similar to the trials-delay procedure, which we discussed earlier in this chapter).

An alternative answer is one we have seen related to many of the issues discussed in this book. The "optimal" summary length may be specific to the skill being learned. Guadagnoli, Dornier, and Tandy (1996) provided evidence for this possibility by showing that longer summaries are better for the learning of simple skills, whereas shorter summaries lead to better learning of more complex skills.

One of the possible strategies people may use when presented with a listing of augmented feedback is to *estimate an average for the series of trials* that the summary includes. The research literature provides some evidence that this may occur. In experiments in which the learner receives the average score for all the trials in a series, the results have shown that this procedure leads to better learning than presenting augmented feedback after every trial (Young & Schmidt, 1992), and no better or worse than after every trial or after every third trial (Wulf & Schmidt, 1996). But when compared to the summary technique, no differences are found in terms of their influence on skill learning (Guay, Salmoni, & Lajoie, 1999; Weeks & Sherwood, 1994; Yao, Fischman, & Wang, 1994).

Finally, *why are these two feedback presentation methods effective?* Their effectiveness is undoubtedly due to the same factors that lead to the benefit of reducing augmented feedback frequency, as explained by the guidance hypothesis. During practice trials on which they receive no augmented feedback, people engage in beneficial learning activities that are not characteristic of people who receive augmented feedback after every trial.

SUMMARY

- Augmented feedback is performance-related feedback that is provided by an external source; it adds to or enhances *task-instrinsic feedback,* which is performance-related feedback directly available to the sensory system during the performance of a skill.
- Two types of augmented feedback are distinguished on the basis of the aspect of a skill performance to which the information refers:
  - *Knowledge of results (KR)* refers to the performance of a skill.
  - *Knowledge of performance (KP)* refers to the movement-related characteristics associated with the outcome of the performance of a skill.
- Augmented feedback plays two roles in the skill learning process:
  - To facilitate achievement of the action goal of the skill.
  - To motivate the learner to continue to strive toward the achievement of a goal.
- The need for augmented feedback for skill learning can be described in four different ways:
  - It can be essential for skill learning.
  - It may not be essential for skill learning.
  - It can enhance skill learning beyond what is possible without it.
  - It can hinder skill learning.
- Augmented feedback content issues include the following:
  - Should the information conveyed to the learner refer to the errors made or to those aspects of the performance that were correct?

- ► Should the augmented feedback be KR or KP?
- ► Should the augmented feedback be quantitative or qualitative?
- ► Should the augmented feedback be based on the size of the error(s) and/or number of errors?
- ► What is the effect of erroneous augmented feedback on skill learning?

- KP can be presented to the learner in several different forms:
  - ► Verbal KP, which can provide either descriptive or prescriptive information.
  - ► Video replays of skill performances.
  - ► Movement kinematics associated with a performance of a skill.
  - ► Biofeedback.
- In addition to giving augmented feedback after a person has completed a trial, or after the performance of a skill (i.e., *terminal augmented feedback*), it can be presented during the performance (i.e., *concurrent augmented feedback*).
- Concurrent augmented feedback can have negative and positive effects on skill learning.
- Two intervals of time associated with terminal augmented feedback are the KR-delay interval and the post-KR interval. Both require a minimum length of time, although a maximum length has not been determined. Engaging in activity during these intervals can hinder, benefit, or have no effect on skill learning.
- Research indicates that the optimal frequency for giving augmented feedback is less than on every practice trial. The guidance hypothesis represents the most commonly held view for explaining the learning benefit of a reduced frequency.
- Several techniques will reduce augmented feedback frequency:
  - ► Performance-based bandwidths.
  - ► Performer-selected frequency.
  - ► Summary and averaged augmented feedback.

POINTS FOR THE PRACTITIONER

- Evaluate the need for KR or KP in any skill instruction situation in terms of the type of augmented feedback that would most effectively facilitate learning the skill.
- More specific or technologically sophisticated augmented feedback is not necessarily better. Beginners need feedback that will help them make a "ballpark" approximation of the movements they need to make to achieve the action goal.
- Augmented feedback that is a combination of error-correction information and information about what was done correctly can be helpful for skill acquisition and motivation to continue to try to achieve the action goal of the skill.
- Determine the verbal KP to give according to the most critical error made during a practice attempt. Identify this error on the basis of an analysis of the skill's component parts and a prioritized list of the importance of each part for achieving the action goal.
- Prescriptive verbal KP is better than descriptive verbal KP for beginners.
- Video replays can be effective as augmented feedback for beginners when you point out errors and provide information about how to correct them. The decision to provide this type of information for more skilled individuals can be based on the individual's choice.
- Computer-generated displays of the kinematics of a skill performance will be more effective for learners who are at a more advanced stage of learning than a beginner.
- Biofeedback can be effective to facilitate skill learning when it provides information people can use to alter movements and when they do not become dependent on its availability.
- Do not feel compelled to give augmented feedback after every practice attempt. When you do not give augmented feedback, you provide opportunities for people to determine what their own sensory feedback tells them about performing the skill they are learning.
- The performance-bandwidth strategy of providing augmented feedback can be especially useful when instructing groups of individuals where it is difficult to interact with each person individually on every performance attempt.
- Allow people you are working with to determine when they would like to receive KR or KP.
- On occasion, ask the people you are working with to tell you what movement errors they made and how they should correct them before you give them this information.

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INTERNET RESOURCES

- To read about a popular video-based performance analysis program that can be used to provide augmented feedback in sports, physical education, and physical rehabilitation settings, go to http://www.dartfish.com.
- To read a summary of a study, funded by the National Athletic Trainers Association (NATA) Foundation, which investigated the use of augmented feedback to help people decrease impact forces of a jump landing, go to http://www.natafoundation.org/refgrants/Onate.pdf. This report was published in the Supplement to the *Journal of Athletic Training,* April–June, 2000, Vol. 38, No. 2, pp. 19–20, and was included in a presentation at the 2003 NATA Annual Meeting in St. Louis, Missouri.
- To read an article for rowing coaches about the use of augmented feedback to change a rower's technique, go to http://www.brianmac.demon.co.uk/articles/scni19a4.htm.

- To read a summary of the development and use of a training system, which involves a virtual environment and augmented feedback, designed to assist in the physical rehabilitation of people with neurological impairments, go to http://web.mit.edu/bcs/bizzilab/members/holden/. Included on this page is a list of articles the researcher has published concerning the training system.
  To read about other projects in this laboratory at M.I.T., go to http://web.mit.edu/bcs/bizzilab/.

STUDY QUESTIONS

1. (a) Describe the two general types of performance-related feedback a person can receive during or after performing a motor skill. In your description, indicate the characteristic that differentiates the two. (b) Discuss why the distinction between these two types of feedback is important.
2. What are the two types of information referred to by the terms KR and KP? Give two examples of each.
3. Describe skill learning conditions where augmented feedback would (a) be necessary for learning, (b) not be necessary for learning, and (c) not be necessary for learning but would enhance learning beyond what would occur without it.
4. (a) How do quantitative and qualitative augmented feedback differ, and how do they influence the learning of motor skills? (b) Describe how you would use these two forms of augmented feedback in a motor skill learning situation.
5. Describe a situation in which you would use video replay as a form of augmented feedback to (a) help a beginner learn a new skill, (b) help a skilled person correct a performance problem. Indicate why the video replay would facilitate learning for each situation.
6. Describe a situation in which you would use kinematic information as augmented feedback to help someone learn a motor skill and explain why you would use it.
7. Describe a skill learning situation in which you would use some form of biofeedback. Indicate how you would use it, and why you would expect it to facilitate the learning of the skill.
8. What is the difference between concurrent and terminal augmented feedback? Give two examples of each.
9. (a) What are two types of activity during the KR-delay interval that have been shown to benefit skill learning? (b) Why does this benefit occur?
10. (a) What seems to be the most appropriate conclusion to draw regarding the frequency with which an instructor should give augmented feedback during learning? (b) How does the guidance hypothesis relate to the issue of augmented feedback frequency?
11. Describe a skill learning situation in which (a) giving summary augmented feedback would be a beneficial technique, (b) using the self-selected frequency strategy would be beneficial.

Specific Application Problem:
Select a motor skill that you might teach in your future profession. Your supervisor has asked you to develop and defend a plan for providing augmented feedback for this skill for the people you will work with. In your plan, describe the skill you will teach and relevant characteristics of the people you will teach. In your defense of this plan, emphasize why the type of augmented feedback you will use and how you will deliver it would be preferable to other types and uses of augmented feedback.

UNIT SIX

Practice Conditions