UNIT SIX

Practice Conditions

CHAPTER 16 Practice Variability and Specificity

Concept: Variability of practice experiences is important for learning motor skills.

After completing this chapter, you will be able to

- Explain the meaning of the term *practice variability* and its relation to predictions of theories of motor skill learning
- Discuss ways to implement practice variability in skill learning or relearning contexts
- Describe how the *contextual interference effect* relates to organizing variable practice
- Discuss the relevance of contextual interference as a basis for scheduling practice for novice learners and skilled performers
- Identify reasons why contextual interference benefits motor skill learning
- Describe the practice specificity hypothesis and contrast it with the practice variability hypothesis
- Discuss how *especial skills* challenge the practice specificity and practice variability hypotheses

APPLICATION

A primary reason a person practices a skill is to increase his or her capability of performing it in future situations that will require the skill. For example, a basketball player needs to be successful shooting free throws in games. A student in a physical education class who will receive a grade based on performance on skills tests wants to practice those skills in ways that will lead to a high level of performance on the tests. Dancers need to perform in recitals, performances, and competitions. Athletic trainers practice taping an ankle or knee so they can do it effectively and quickly with athletes when needed. And physical rehab patients practice skills so that they can perform them as needed in their everyday environment. Because of this future performance requirement, teachers, coaches, athletic trainers, and therapists must design and establish practice conditions that will lead to the greatest probability of successful performance in situations that will require the practiced skills.

Consider two more specific examples. Suppose you were taking golf lessons, and your instructor told you to go to the practice range and hit a basket of practice balls. You know you need practice hitting your long irons. What would be the best way for you to spend your practice time using your long irons so that you can improve your performance with those irons when you play a round of golf on the golf course? Or suppose you are a physical therapist working with a patient who recently had knee replacement surgery. You want the patient to work on ascending and descending stairs. What would be the most effective way to schedule the practice of these two tasks to facilitate your patient's capability to ascend and descend the stairs in his or her home every day?

One practice characteristic that increases the chances for future performance success is the variability of the learner's experiences while he or she practices. This includes variations of the characteristics of the context in which the learner performs the skill, as well as variations of the skill he or she is practicing. The practitioner must address several important questions to determine how to optimize the types and amount of variation to include in practice experiences. First, what aspects of performing the skill should he or she vary? Second, how much variety of experiences is optimal? Third, how should the variety of experiences be organized in the practice sessions? We consider these questions in the discussion that follows.

Application Problem to Solve Describe a motor skill that involves the performance of several variations. If you were teaching or helping people rehabilitate their performance of these variations, how would you schedule them to be practiced in the period of time you have available? Why would you consider this practice schedule to be better than any other schedule that could be created?

DISCUSSION

The theories of motor skill learning and control we have discussed in this book, consistently emphasize the learning and performance benefits derived from practice variability. In these theories, **practice variability** refers to the variety of movement and context characteristics the learner experiences while practicing a skill. For example, in Schmidt's (1975) schema theory, a key prediction is that successful future performance of a skill depends on the amount of movement variability the learner experiences during practice. Similarly, Gentile's learning stages model (1972, 2000) emphasized the learner's need during practice to experience variations of regulatory and nonregulatory context characteristics. And dynamical systems views of skill learning stress the learner's need to explore the perceptual motor workspace and to discover optimal solutions to the degrees of freedom problem posed by the skill (e.g., McDonald, Oliver, & Newell, 1995; Vereijken & Whiting, 1990).

THE FUTURE PERFORMANCE BENEFIT OF PRACTICE VARIABILITY

An important benefit a learner derives from practice experiences that promote movement and context variability is an increased capability to perform the skill in a future test situation. This means that the person has acquired an increased capability not only to perform the practiced skill itself, but also to perform the skill in novel conditions that might characterize the test situation, such as in a competitive event. When viewed from the perspective of transfer of learning, where the transfer of interest is from practice to the test, the inclusion of movement and context variability in practice can be seen as a means of enhancing positive transfer from the practice to the test contexts.

Variable versus Constant Practice

One way to establish that practice variability benefits future performance is to compare the effects on retention or transfer test performance of practice situations involving one variation of a skill (i.e., *constant practice*) with those involving several variations of the skill (i.e., *variable practice*). This type of comparison has been the standard research strategy for testing Schmidt's (1975) schema theory hypothesis that greater amounts of variable practice lead to better learning than lesser amounts. Although an abundance of published research studies have investigated and generally supported this hypothesis (see van Rossum, 1990, for a review of this research), two examples will illustrate these studies.

In two experiments, Shea and Kohl (1990, 1991) had participants learn to apply 175N of force while pressing a handle. One experimental group, the constant practice group, practiced only this skill for 289 trials, while a variable practice group practiced producing four different amounts of force (125N, 150N, 200N, and 225N). Notice that none of the amounts of force practiced by the variable practice group was the 175N goal. When both groups performed a retention/transfer test for the 175N goal (the test was a retention test for the constant group but a transfer test for the variable group), the variable group performed more accurately than the constant group.

practice variability the variety of movement and context characteristics a person experiences while practicing a skill.

Variable practice was also shown to result in better learning than constant practice in an experiment involving a sports skill (Shoenfelt, Snyder, Maue, McDowell, & Woolard, 2002). In this study, participants practiced shooting basketball free throws. The results, which can be seen in figure 16.1, showed that the constant practice group, which practiced only from the free-throw line, improved during the three weeks of practice, but two weeks later on a retention test, returned to their pretest level of performance. On the other hand, three variable practice groups, only one of which included shooting from the free-throw line, improved during practice and performed on the retention test at a higher level than they had on the pretest.

Performance errors benefit learning. An apparent irony concerning the benefit of an increased amount of practice variability is that it is usually associated with an *increased amount of performance error during practice.* However, this relationship is consistent with research evidence that shows more performance error can be better than less error for skill learning, when it occurs in the initial learning stage. A good example of this evidence is an experiment by Edwards and Lee (1985). Each participant had to learn to move his or her arm through a specified pattern in 1,200 msec. Participants in the prompted group engaged in practice designed to minimize performance errors. They were told that if they moved according to a "ready and 1, 2, 3, 4, 5" count on a tape, they would complete the movement in the criterion time. Each person practiced until he or she could do three trials in a row correctly at 1,200 msec. Those in the trial-and-error group were told the goal movement time and received knowledge of results (KR) about their timing error after each trial. The results indicated that the two groups performed similarly on the retention test, but the trial-and-error group performed more accurately on a transfer test when both groups had to move in a different amount of time, which was 1,800 msec.

What is particularly interesting about these results is how much the two groups differed in the amount of error each produced during practice. The prompted group performed with very little error during practice, whereas the trial-and-error group experienced much error, especially during the first fifteen trials. Yet experiencing less error during practice was not more beneficial for retention test performance, and it was detrimental for transfer to a novel variation of the practiced movement.

Similar results have been reported in a physical rehabilitation setting. For example, when acute stroke patients were instructed, by either a trial-and-error or errorless learning method, to put on a sock, those who practiced by trial-and-error performed better on a transfer test that involved a variation of the practiced task (Mount, Pierce, Parker, DiEgidio, Woessner, & Spiegel, 2007). Although the physical rehabilitation research literature presents some evidence that shows the benefits of instructional strategies that minimize the amount of performance errors by people with specific cognitive disorders (see Mount et al., 2007, for a brief review of this research), the effectiveness of "errorless" learning strategies does not carry over to healthy populations and it has not been replicated consistently in people with cognitive disorders.

A study by Lee et al. (2016) has clarified that the nature of the errors made by learners, rather than the quantity of errors, seems to be the factor most responsible for the positive effects of errors on learning. Participants in the study learned a key-press sequencing task under conditions that varied the amount of information about which key to press next in the sequence and therefore encouraged different amounts of error. The primary finding was that retention of the sequences was better when more errors were made during practice. However, not all types of errors had the same beneficial effect on learning. The benefits came from errors that gave learners an opportunity to fully engage in the error detection and correction processes that enabled them to evaluate their decision making strategies. In contrast, errors that were induced by making decisions difficult to evaluate during practice did not have the same facilitatory effect on learning.

IMPLEMENTING PRACTICE VARIABILITY

An important instruction planning decision is determining how to provide practice variability during practice sessions for learning a skill. The first step in making this decision is to assess the characteristics of

A CLOSER LOOK

Constant and Variable Practice for Learning to Shoot Free Throws in Basketball

The experiment by Shoenfelt, Snyder, Maue, McDowell, and Woolard (2002) involved university students who were not skilled basketball players practicing basketball free throws.

Practice and Test Schedules

Pretest	40 free throws (20 sets of 2 shots)
Practice	40 free throws per day (blocks of 10 shots) T, W, Th, F each week for 3 weeks
Weekly tests	Each Monday's session of 40 free throws (20 sets of 2 shots) was a weekly progress test
Retention test	40 free throws (20 sets of 2 shots) two weeks after the last practice session

Practice Variability Conditions

Constant practice (C)	Free-throw shooting from the free-throw line only
Variable practice—Front & Back (VFB)	Free-throw shots from 2 ft in front of and 2 ft behind the free-throw line (randomly assigned in each practice session)
Variable practice—Combination (VC)	Free-throw shots from 2 ft in front of and 2 ft behind the free-throw line as well as from the free-throw line (randomly assigned in each practice session)
Variable practice—Random (VR)	Free-throw shots from the "elbow" to the left and to the right of the key, and from the top of the key (randomly assigned in each practice session)

Results

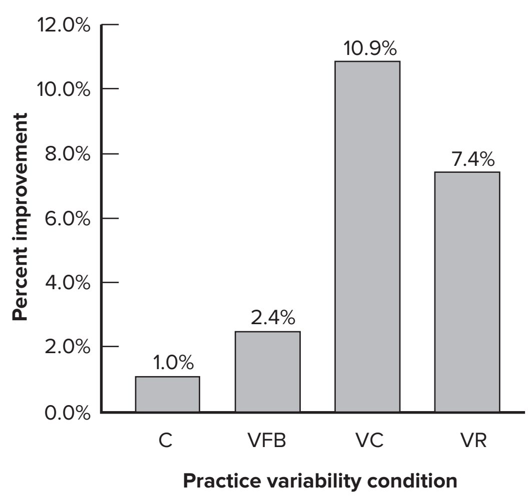


FIGURE 16.1 Results from the experiment by Schoenfelt et al. showing the pre- to posttest percentage of improvement for the four practice variability groups (C = Constant practice; VFB = Variable Front and Back practice; VC = Variable Combination practice; VR = Variable Random practice). *Source:* Data from Schoenfelt, E. L., Snyder, L. A., Maue, A. E., McDowell, C. P., & Woolard, C. D. (2002). Comparison of constant and variable practice conditions on free-throw shooting. *Perceptual and Motor Skills, 94,* 1113–1123.

the future situations in which the learner will perform a skill. Of particular relevance here are the *characteristics of the physical context* in which he or she will perform the skill and the *skill characteristics* that the performance situation will require. If you again view this situation as a transfer of learning situation, then you will see the value of using the test conditions to determine what the practice environment

LAB LINKS

Lab 16 in the Online Learning Center Lab Manual provides an opportunity for you to experience and compare the effects of constant and variable practice on learning a motor skill.

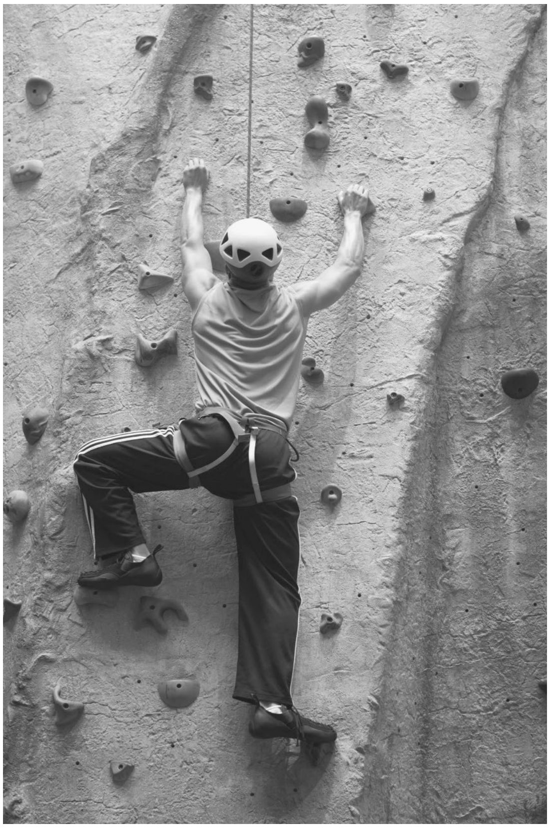
should be like. As we discussed in chapter 13 and illustrated in figure 13.1, effective transfer is a function of the similarities between skill, context, and cognitive processing characteristics of the practice and test situations. A high degree of similarity between these characteristics in the two situations enhances transfer between the practice and the test.

Varying Practice Contexts

It is important to keep in mind that when people perform skills, they do so in contexts that have identifiable characteristics. As we discussed in chapter 1 and as proposed by Gentile (2000), movements must directly conform to specific features of the environmental context (which she called regulatory conditions), whereas other features (nonregulatory conditions) have no influence or only an indirect influence on movement characteristics.

For example, some *regulatory conditions* that influence a person's walking behavior are different when you walk on a concrete sidewalk than when you walk on ice or on sand. Also, you walk differently on a busy sidewalk that is cluttered with other people than on a sidewalk empty of people. When regulatory conditions like these may vary from one performance context to another, practice conditions should include a variety of similar conditions.

Nonregulatory conditions for walking would include the physical environment around the walking pathway, such as buildings, trees, and open space as well as the sounds that are typically present in the environment. Although these features do not influence the movements directly, we know from our study of incidental memory in chapter 10 that they can influence the degree of success a person may achieve in carrying out the action in a unique context. Again, when nonregulatory conditions will vary from one performance context to another, practice conditions should provide opportunities to experience these characteristics.



Varying the regulatory conditions by practicing on different climbing walls will increase a climber's capability to adapt to new situations.

Corbis/age fotostock

Varying Practice Conditions for Closed Skills

As we discussed in chapter 1, closed skills can be sub-divided into whether or not the skill involves intertrial variability, which concerns the regulatory conditions remaining the same on the next trial (such as for shooting freethrows in basketball) or varying (such as for golf). The first step in making the decision about what to vary during the practice of a closed skill is to determine whether or not the skill involves intertrial variability for the regulatory conditions in the test situation. *For closed skills that do not involve intertrial variability of regulatory conditions,* such as

TABLE 16.1 Examples of Varying Practice Conditions for Two Types of Closed Skills

Intertrial Variability of Regulatory Conditions	No Intertrial Variability of Regulatory Conditions
Golf shot using a 7-iron The goal is to successfully make shots with the 7-iron during a golf match.	**Basketball free throw** The goal is to shoot free throws successfully in basketball games.
Regulatory conditions that remain constant in a match • 7-iron characteristics • golf ball characteristics	**Regulatory conditions that remain constant in games** • basket height • basket distance from free-throw line • basketball characteristics
Regulatory conditions that can vary in a match • width of the fairway • distance of required shot • location of ball	**Nonregulatory conditions that can vary in games** • number of free throws to be taken • importance to game of making the free throws • crowd noise • length of the game
Nonregulatory conditions that can vary in a match • number of playing partners • number of strokes ahead or behind • cloudy or sunny skies • importance of a particular shot	*Practice conditions* should include as many *nonregulatory* conditions as possible to be similar to those that could be experienced in a game.
Practice conditions should simulate as many *regulatory* and *nonregulatory* conditions as possible to be similar to those that could be experienced in a match.	

competition darts, only the nonregulatory conditions may be novel. For the practice of these types of skills, regulatory conditions such as the distance to the target and the weight of the darts should remain constant (although there may be exceptions, but not varying regulatory conditions would be the first option to use), but nonregulatory conditions like the degree of lighting should vary according to expectations for the test situation. *For closed skills that involve intertrial variability,* both regulatory and nonregulatory conditions are likely to be novel in the test situation, which means that both should be varied in practice. Examples of practice condition characteristics for each of these types of closed skills are presented in table 16.1.

Varying Practice Conditions for Open Skills

Each performance of an open skill is unique, because in each performance of the skill, certain characteristics of the movements must match the unique movements required by the regulatory conditions. That is, to perform the skill the person must produce certain movements that he or she has not made before in exactly the same manner this situation requires. The performer needs to modify previously produced movements in order to achieve the goal of the skill. For example, if you are preparing to return a serve in tennis, it is likely that certain characteristics of the ball action will be unique to this particular serve. Thus, in addition to variations of nonregulatory conditions, practice of open skills also needs to include a variety of experiences with regulatory conditions that change from one attempt to another.

ORGANIZING VARIABLE PRACTICE

Because we know that experiencing practice variability benefits skill learning, it is important that we next consider how to organize the variable experiences

		Class day					
		1	2	3	4	5	6
Blocked practice	30 min	All overhand	All overhand	All underhand	All underhand	All sidearm	All sidearm
Random practice	5 min 5 min 5 min 5 min 5 min 5 min	Underhand Overhand Underhand Sidearm Underhand Overhand	Overhand Sidearm Sidearm Underhand Overhand Overhand	Sidearm Overhand Sidearm Underhand Underhand Sidearm	Overhand Sidearm Sidearm Underhand Overhand Overhand	Underhand Overhand Underhand Sidearm Underhand Overhand	Sidearm Overhand Sidearm Underhand Underhand Sidearm
Serial practice	5 min 5 min 5 min 5 min 5 min 5 min	Overhand Underhand Sidearm Overhand Underhand Sidearm	Overhand Underhand Sidearm Overhand Underhand Sidearm	Overhand Underhand Sidearm Overhand Underhand Sidearm	Overhand Underhand Sidearm Overhand Underhand Sidearm	Overhand Underhand Sidearm Overhand Underhand Sidearm	Overhand Underhand Sidearm Overhand Underhand Sidearm

FIGURE 16.2 A six-day unit plan demonstrating three different practice structures (blocked, random, and serial) for teaching three different throwing patterns (overhand, underhand, and sidearm). All classes are 30 min long and all but the blocked practice schedule are divided into 5 min segments. Each practice condition provides an equal amount of practice for each throwing pattern.

within a practice session or unit of instruction. For example, suppose you are an elementary school physical education teacher organizing a teaching unit on throwing for your classes. You have determined that you will devote six class periods to this unit. You want the students to learn three variations of the throwing pattern: the overhand, underhand, and sidearm throws. The practice organization question for this situation is this: How should you arrange these three different throws for practice during the six class periods? Figure 16.2 shows three possible arrangements. One is to practice each throw in blocks of two days each (blocked practice). Another possibility is to practice each throw in a random arrangement with 5 min blocks devoted to each particular pattern (random practice). Thus, each day students would experience six 5 min blocks, with no specified order of occurrence for the three patterns; the only stipulation would be that they practice all three an equal amount over the course of the unit. The third arrangement, serial practice, also involves a 5 min block for each pattern. However, in this approach students practice each pattern for two sets of 5 min every day in the same order.

This organization question is not unique to physical education. It applies to any situation in which learners must practice and learn several variations of a skill. Consider a few examples. In a therapy situation, a patient may need to practice grasping objects of different sizes, weights, and shapes. A patient who has had a knee joint replacement may need to practice walking on different types of surfaces. In a dance setting, a dancer may need to practice tempo variations in a routine or other variations of particular components of a routine. Each of these situations involves the same organization problem: How should the schedule of practice for these variations be organized within the practice time available?

The Contextual Interference Approach to Organizing Variable Practice

One answer to the variable practice schedule question is to apply the learning phenomenon known as the *contextual interference effect.* William Battig (1979), who first demonstrated this effect, introduced the term **contextual interference** to refer to the *interference* (recall the definition and use of this term in chapter 10 in our discussion of influences on forgetting in memory) that results from performing various tasks or skills within the *context* of practice. This means that practice sessions can include experiences that disrupt memory while practicing a skill or skills.

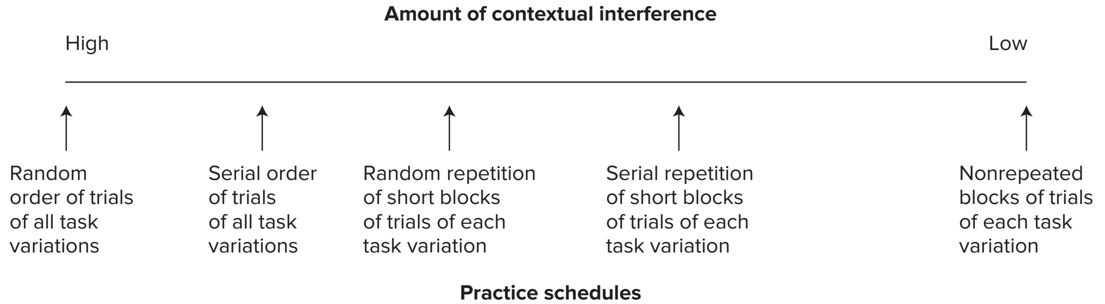


FIGURE 16.3 The amount of contextual interference that is possible in a practice situation is portrayed as a continuum ranging from high to low. Also presented are some sample variable practice schedules in terms of how each relates to the amount of contextual interference created by the schedule.

The way a practice schedule is organized will involve different amounts of contextual interference. The blocked, random, and serial practice schedule organization options described earlier, each represent different amounts of contextual interference, which can be viewed as located along a continuum of the amount of contextual interference (see figure 16.3). A *high amount of contextual interference* occurs at one extreme, when the practice schedule involves a random arrangement of trials so that all the task variations are performed in each practice session. In this schedule, the task variation practiced on each trial would be randomly determined. At the opposite extreme, a *low amount of contextual interference* results from a schedule that organizes the practice of each task variation in its own block, or unit, of time. Other schedules, such as the serial schedule described earlier, fall along the continuum between these two extremes. It is important to note here that the different types of practice schedules can be based on trials, as they are in figure 16.3, or on time intervals. For developing practice schedules associated with contextual interference either trials or time intervals are appropriate.

The **contextual interference effect** occurs when *a high amount of contextual interference results in better learning* (i.e., retention and transfer performance) of the task variations than a low amount. What is especially noteworthy about this effect is that prior to Battig's initial demonstration of it, researchers traditionally viewed interference as something that hinders learning. According to that view, a low amount of contextual interference during practice should lead to better learning than a high amount. However, Battig's research showed an important exception to the traditional view of interference. It is important to note in this regard that a negative influence of interference is often found for high contextual interference schedules during practice. But this interference turns out to benefit learning because the high contextual interference practice schedules result in better performance on retention and transfer tests than low contextual interference practice schedules.

Research Evidence for the Contextual Interference Effect

The first evidence of the contextual interference effect for motor skill learning was reported by Shea and Morgan (1979). Participants practiced three variations of movement patterns in which the goal was to move one arm through a series of small wooden barriers as rapidly as possible. One group followed a blocked practice schedule (i.e.,

contextual interference the memory and performance disruption (i.e., interference) that results from performing multiple skills or variations of a skill within the context of practice.

contextual interference effect the learning benefit resulting from performing multiple skills in a high contextual interference practice schedule (e.g., random practice), rather than performing the skills in a low contextual interference schedule (e.g., blocked practice).

A CLOSER LOOK

A Professional Golfer's Use of Random Practice

Amy Alcott, a professional golfer on the LPGA tour and member of the World Golf Hall of Fame, described in *Golf Magazine* (December, 1991) a drill she used to help her make a swing of the correct length and strength for the distance. She practiced pitch shots that are 20, 40, 60, and 80 yards from flags marking each distance. Before she hit a ball, her teacher, Walter Keller, called out the yardage for the shot. She looked at the flag, set up, and swung. Then, her teacher called out another yardage for the next shot. She says that "One after another, he'd call out yardages—60, 20, 40, 80, 40, 60." Alcott states that she finds this type of practice "invaluable," and repeated it from time to time throughout the season.

low contextual interference) in which each movement pattern was practiced in its own unit of trials. A second group practiced according to a random schedule (i.e., high contextual interference) in which the practice of each pattern was randomly distributed throughout the practice trials. An important point here is that both groups practiced for the same number of trials, only the scheduling of trials differed.

Results showed that the random practice schedule led to poorer performance during practice, but better performance on retention and transfer tests. Thus, random practice resulted in better learning of the three pattern variations and allowed for better performance for a new pattern. Since the Shea and Morgan experiment, numerous other studies have been reported (see Brady, 1998; Lee, 2012; Magill & Hall, 1990; Pauwels, Swinnen, & Beets, 2014). The evidence from this research establishes that the contextual interference effect is generalizable to learning motor skills.

One of the striking negative effects of low contextual interference practice is that it inhibits performance of the practiced skills in novel performance contexts. Contextual interference experiments commonly show this. Although blocked practice sometimes leads to blocked retention test performance that is similar to performance following random practice, a large decrement in retention performance is typical when researchers test the skills under random conditions (e.g., Shea, Kohl, & Indermill, 1990). On the other hand, high contextual interference practice does not show the same transfer problem. Thus, low contextual interference practice appears to develop a practice context dependency that decreases a person's capability to adapt to novel test contexts.

The contextual interference effect outside the laboratory. Battig's original demonstration of the contextual interference effect was based on the learning of cognitive skills, such as word lists. Much of the research involving motor skills has been based on the learning of laboratory tasks, such as the barrier-knockdown task used by Shea and Morgan (1979). If we want to have confidence in the application of laboratory-based principles of motor learning to real-world contexts, it is important to establish that learning phenomena demonstrated in the laboratory also exist in real-world settings. We will look at a few examples of research that provide evidence that the contextual interference effect occurs in learning situations outside the laboratory.

One of the first experiments that presented this type of evidence was reported by Goode and Magill (1986). College women with no prior badminton experience practiced the short, long, and drive serves from the right service court. They practiced these serves three days a week for three weeks with 36 trials in each practice session, for a total of 324 trials (108 trials per serve) during the practice period. The low contextual interference condition was a modification of the blocked condition used in previous studies; in this study, the blocked practice group practiced one serve each day of each week. The group on a random practice schedule practiced each serve randomly in every practice session. In this condition, the experimenter told each participant which serve she should perform next.

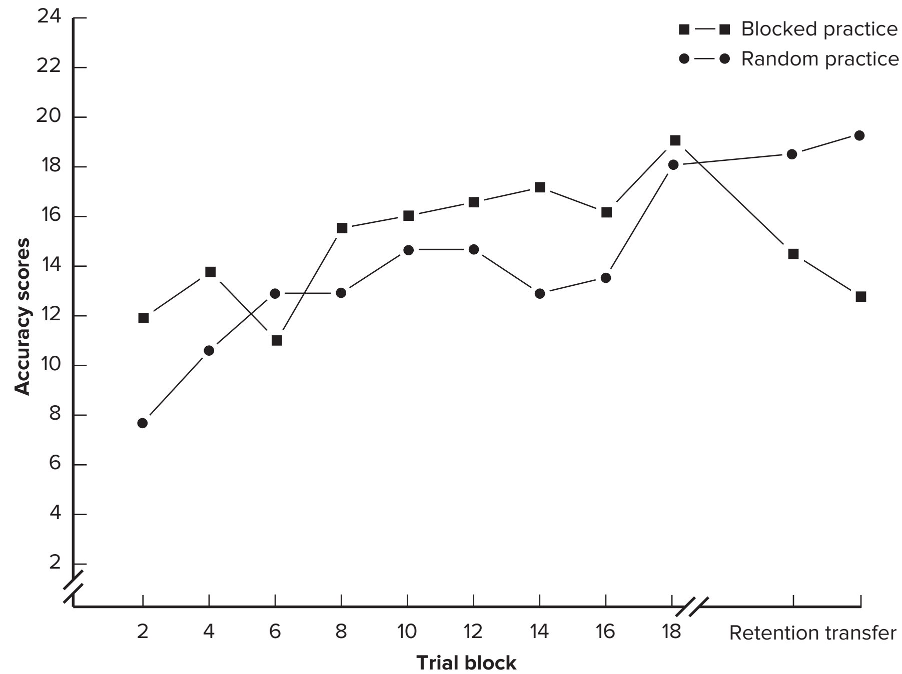


FIGURE 16.4 Results from the experiment by Goode and Magill showing the effects of blocked and random schedules of practice for three types of badminton serves on acquisition, one-day retention, and transfer. *Source:* From *Research Quarterly for Exercise and Sport, 57*(4), 308–314.

As you can see in figure 16.4, the results demonstrated the contextual interference effect. The group that practiced with the random schedule outperformed the blocked practice group on the retention and transfer tests. What is especially remarkable is that on the transfer test, which involved serving from the left service court, the random group showed no deterioration in performance. On the other hand, students in the group that had practiced in a blocked schedule were not able to adapt well to this new performance context. In fact, learners in this group performed in the new context about as well as they had when they had begun practicing the serves from the right court three weeks earlier.

A study by a group of researchers in Greece (Tsopani, Dallas, Tasika, & Tinto, 2012) showed the contextual interference effect for novice university female rhythmic gymnasts. The study compared two practice schedules. One involved the traditional blocked practice approach (traditionally used by the university training program), which had gymnasts practice all the trials for one apparatus before beginning practice on another apparatus. The other schedule required the gymnasts to follow a serial-type schedule in which they practiced trials for each apparatus in a specified sequence in each practice session. On a retention test following the nine weeks of practice sessions (two 90-min. sessions per week), all the participants were judged on their technical and artistry performance on each apparatus. Results showed that the gymnasts who followed the serial-practice scheduled performed at a higher level than those who used the traditional blocked schedule. The two studies just discussed showed the benefit of high contextual interference for *beginners* learning actual sport skills (three badminton serves and several rhythmic gymnastics skills). However, although their experiments used sport skills, the authors carried them out in controlled experimental conditions. Those who seek even more real-world validity should note that Wrisberg and Liu (1991) attained the same results as Goode and Magill, but in an actual class setting. In that study, students learned the badminton serves in a unit of instruction in an actual physical education class.

Another experiment worth noting demonstrates that the contextual interference effect for real-world skills exists not only for beginners, but also for *skilled individuals.* Hall, Domingues, and Cavazos (1994) had skilled baseball players practice hitting different types of pitches to improve their batting performance. The players engaged in forty-five extra pitches of batting practice three days a week for five weeks. Batters hit fastballs, curves, or change-ups according to a blocked or random schedule. In the blocked schedule, players practiced hitting one of these pitches on each day, whereas in the random schedule, they hit all three types of pitch, randomly presented, each day. The results showed that on a test involving a random sequence of pitches, like one that would occur in a game, players who had experienced the random practice schedule performed better than those who had practiced according to the blocked schedule.

In addition to these few examples, several other studies have found evidence that demonstrates the contextual interference effect for the learning of real-world skills. These include basketball shooting skills, tennis groundstrokes, volleyball serves, rifle shooting, knot tying, handwriting skills, chiropractic spine manipulation, and computer game skills (see Brady, 1998; Enebo & Sherwood, 2005; Ollis, Button, & Fairweather 2005; Ste-Marie, Clark, Findlay, & Latimer, 2004, for discussions of the various studies involving these skills). The contextual interference effect has also been found for the learning of perceptual-cognitive skills that underlie anticipation and decision making in sports (e.g., Broadbent, Causer, Ford, & Williams, 2015; Broadbent, Causer, Williams, & Ford, 2017). When considered together with the research based on laboratory tasks, research involving real-world skills establishes the contextual interference effect as an important motor learning phenomenon.

Contextual Interference Influences Judgments about Learning

In chapter 11, you saw some examples of situations in which performance during practice misrepresents the amount of learning occurring during practice. The contextual interference effect is another example of this type of situation. In fact, not only does practice performance misrepresent the amount of learning, it also influences the learners' judgments about how much they are learning depending on which practice schedule they experienced. Judgment about how much we are learning while we practice is referred to as *metacognition,* which concerns "what we know about what we know." The assessment of this information is typically done by asking people to predict how well they think they will do on a retention test. A study by Simon and Bjork (2001) demonstrated that people who used a blocked schedule for practicing three goal movement times and patterns of a five-key sequence of numbers on a computer number pad consistently overestimated their performance on a test that would occur the next day. In contrast, participants who followed a random practice schedule more accurately estimated their test performance (see figure 16.5).

Why would this type of overestimation of learning occur for the blocked practice schedule? The most likely reason is that because people perform relatively well using this schedule they use their level of performance during practice as the basis for predicting how well they will perform the next day. But because they are not learning as much as their performance would indicate, they do not perform the next day as well as they expected because the contextual interference effect influenced their learning during practice.

What Are the Limits of the Contextual Interference Effect?

Although researchers have provided a large amount of evidence supporting the existence of the contextual interference effect, they also have shown that it does not apply to all motor skill learning situations. As a result, a question arises concerning the characteristics that limit the generalization of the effect, which concerns how broadly the effect can be applied. Both task and learner characteristics have been the focus of speculations and investigations of this issue.

Motor skill characteristics. In the first comprehensive review of the research literature, Magill and Hall (1990) hypothesized that the contextual interference effect would more likely be found

A CLOSER LOOK

Judgments about How Much People Are Learning during Practice

An important study by Simon and Bjork (2001) investigated how well people who are practicing multiple variations of a motor skill can assess their own learning during practice, which is commonly referred to as *metacognition.* The significance of their study is twofold. First, it was the first investigation of metacognition as it relates to the learning of motor skills (it has a longer history in the study of verbal-conceptual learning; see Nelson, 1992). Second, it demonstrated that practicing multiple variations of a motor skill with a low amount of contextual interference influences learners to be overconfident about how well they will perform on an upcoming test.

The Simon and Bjork (2001) Experiment

Participants: Forty-eight undergraduate university students.

Motor skills practiced: The task required participants to learn to press three specified five-key sequences on the number pad of a computer keyboard. The sequences differed in the patterns of numbers to press and overall goal movement times (MT). (*Sequence 1* was the 9-5-1-2-3 keys with a 900 msec MT goal; *Sequence 2* was the 3-6-5-8-4 keys with a 1,200 msec MT goal; *Sequence 3* was the 4-2-5-8-9 keys with a 1,500 msec MT goal.)

Practice conditions: Participants practiced each sequence in a blocked or random order until they performed thirty successful trials for each sequence; that is, they pressed the correct keys (unsuccessful trials were repeated later in the practice session). Knowledge of results (KR) was provided after each trial in terms of (a) whether or not the correct keys had been pressed, (b) the actual MT for the trial, and (c) the number of milliseconds faster or slower the actual MT was than the goal MT.

- *Blocked practice schedule*—All trials of each sequence were practiced as a unique set of trials until the thirty-trial criterion was achieved for the sequence (e.g., 900—900—900 . . . 1,200—1,200—1,200 . . . 1,500—1,500—1,500 . . .).
- *Random practice schedule*—Each of the three sequences was practiced in a random order until the thirty-trial criterion was achieved for each sequence.

Assessment of participants' judgment of learning (JOL): At the end of every fifth successful trial, participants were asked to predict as closely as possible their estimate of how close they would come to the goal MT for that sequence on a test scheduled for the next day (they were told to predict as if they would receive no additional practice trials).

Retention test: One day after completing the practice trials, participants performed a paper-and-pencil test of their recall of the key-press sequences and goal MTs they practiced the previous day and predicted their expected MT performance in terms of how close they would come to each goal MT. They then performed three trials of each sequence in a blocked order and random order. No KR was provided on any of these trials.

Results:

The top panel of figure 16.5 below shows that the blocked group was significantly more accurate during early practice but significantly less accurate during retention. The bottom panel shows that the blocked group predicted much better performance than the random group during acquisition and retention.

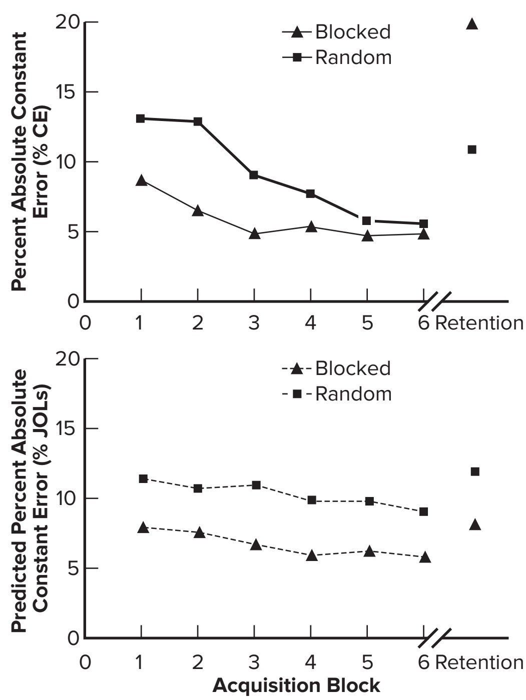


FIGURE 16.5 Top panel: Percent of absolute constant error during acquisition on 24-hr retention test as a function of blocked or random practice during acquisition. Bottom panel: Learner-made predictions (during acquisition and immediately prior to the 24-hr test) of performance on the 24-hr retention test as a function of blocked or random practice. *Source:* Simon, D. A., & Bjork, R. A. (2001). Metacognition in motor learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 907–912.

A CLOSER LOOK

An Application of the Contextual Interference Effect to the Physical Therapy of Stroke Patients

A study by Hanlon (1996) demonstrated the benefit of a random practice schedule for the physical therapy of unilateral stroke patients who needed to rehabilitate the use of their hemiparetic (i.e., partially paralyzed) arm to perform functional movement sequences.

Participants: Twenty-four adult patients with chronic hemiparesis due to a unilateral cerebrovascular accident (CVA), which is commonly called a stroke.

Movement sequence practiced: Participants used their hemiparetic arm to perform a five-step sequence designed to approximate steps needed to (1) open a cupboard door, (2) grasp a coffee cup by the handle, (3) lift the cup off its shelf, (4) place the cup on the counter, and (5) release the grasp.

Practice conditions:

- *Random practice schedule*—Ten trials in one session per day until participants achieved the performance criterion of three consecutive correct trials. Between each trial of the movement sequence, participants performed three other tasks with the hemiparetic arm: (1) pointing, (2) touching specified objects, (3) touching specified spots on a horizontal surface.
- *Blocked practice schedule*—Ten trials in one session per day until participants achieved the performance criterion of three consecutive correct trials.
- *No practice control condition*—No practice trials.

Retention tests: All participants performed the five-step movement sequence for five trials two and seven days after the end of the practice sessions.

Results:

Practice trials:

- No statistically significant difference between the random and blocked practice groups for the mean number of trials required to achieve the performance criterion.

Retention tests:

- The *random practice group* performed significantly more successful trials on both retention tests than the blocked practice group and the no-practice control group.
- Interestingly, the blocked practice group did not differ from the no-practice control group on the number of correctly performed trials on the first retention test, but performed significantly better on the second retention test.

Conclusion: The experiment demonstrated that it is possible to create the contextual interference effect in a clinical setting by interposing other activities between trials, or repetitions, of the skill or activity being rehabilitated. The functional benefit is a longer-lasting performance improvement than would result from repeating repetitions without the intervening activities.

for motor skill variations controlled by different generalized motor programs (discussed in chapter 5) than by the same program. For example, when a person practices learning several skill variations characterized by different relative time patterns, such as would be expected for the three badminton serves described earlier, a high contextual interference practice schedule should lead to better learning than a low contextual interference schedule. However, when the skill variations are characterized by the same relative time patterns, but different overall speeds, there should be no advantage to a high over a low contextual interference practice schedule. When removed from the context of the generalized motor program, the Magill and Hall hypothesis proposed that for the learning of skill variations, the contextual interference effect should be found when the characteristics of the variations are more dissimilar than similar.

Another possible reason for the limited generalization of the effect was presented by Brady (1998). In his assessment of the research that investigated the contextual interference effect, Brady concluded that research involving laboratory tasks tends to support the hypothesis (e.g., Wood & Ging, 1991; Wulf & Lee, 1993). But when research involves applied settings, higher amounts of contextual interference tend to enhance the learning of skill variations that are more similar than different (also see Barreiros, Figueiredo, & Godinho, 2007, and Merbah & Meulemans, 2011). For example, compared to a low contextual interference practice schedule, moderate and high contextual interference practice schedules produced better learning of one-hand basketball set shots from different distances and angles (Landin & Hebert, 1997), but not better learning of three different volleyball skills (French, Rink, & Werner, 1990).

Two reasons may account for this discrepancy between the laboratory and applied settings. First, the learning of sport skills requires more practice than has been included in those studies that have not found the effect. Because sport skills tend to be more complex and difficult than the typical laboratory skills used in contextual interference research, much more practice would be required to learn the sport skills. The second reason is that sport skills may have unique characteristics that may require a practice schedule that increases contextual interference, such as a progression of low to high amounts of contextual interference (see Porter, 2008; Porter & Magill, 2010). Unfortunately, these two possibilities remain speculative until we have a sufficient amount of research evidence that either supports or does not support them. However it is noteworthy that Saemi and colleagues (2012) reported a learning benefit for elementary school children in physical education classes who experienced a progressive low-to-high contextual interference practice schedule.

Learner characteristics. Researchers have also proposed that several *learner characteristics* may limit the effect of contextual interference on skill learning. Of the characteristics suggested, *age and skill level* appear to be the most likely limiting factors. When participants in studies have been children, the highest amounts of contextual interference typically do not enhance learning (e.g., Graser, Bastiaenen, & Hedel, 2019). In fact, Brady's (1998) review points out that for children, practice schedules that produce lower amounts of contextual interference tend to produce better learning. However, as noted above, learning benefits for children were reported by Saemi et al. (2012) when they practiced physical education skills using a progressive low-to-high contextual interference schedule, which emphasizes a low amount of contextual interference early in practice. In terms of skill level, Hebert, Landin, and Solmon (1996) found that low-skilled students in university tennis classes performed forehand and backhand strokes better on a retention test following blocked practice, whereas high-skilled students performed no differently following blocked or alternating-trials practice schedules.

In summary, we know that certain factors limit the extent of the generalization of the contextual interference effect in motor skill learning situations. Unfortunately, we do not have a definitive account of the specific characteristics that establish those limits. Although there is general agreement that both task- and learner-related characteristics influence the degree to which contextual interference influences the learning of motor skill variations, we must wait for much more research evidence to allow us to confidently identify the specific characteristics.

A different but encouraging perspective on the influence of task- and learner-related characteristics on learning was presented by Guadagnoli and Lee (2004). They proposed a *challenge point hypothesis* for determining effective practice conditions based on difficulty characteristics of the tasks and the skill level of the person. The "challenge point" refers to the implementation of specific practice conditions that will optimally challenge the person in a way that will enhance skill learning. Determining the challenge point involves a consideration of both the difficulty level of the skill being learned and the skill level of the learner. There are two types of "task difficulty" here: (1) "nominal," which is task specific and refers to the inherent perceptual and motor requirements of the task (such as were considered in our discussion in chapter 1 of Gentile's Taxonomy of Skills); (2) "functional," which is related to the skill level of the person (i.e., some skills are less difficult for a skilled person to perform than for a novice). The hypothesis makes two predictions concerning the implementation of levels of contextual

A CLOSER LOOK

The Effectiveness of a Moderate Contextual Interference Practice Schedule

It may be preferable to learn some motor skill variations by practicing according to a schedule that involves a moderate rather than a high amount of contextual interference. A study by Landin and Hebert (1997) provides a good example of this type of practice situation.

Participants were university undergraduate students who had very little experience playing basketball. They practiced the one-hand set shot from six positions on the basketball court that varied in angle and distance from the basket. The *low contextual interference* group practiced according to a blocked schedule by shooting six consecutive shots from each position on each of three practice days. The *moderate contextual interference* group followed a blocked-serial schedule by shooting three shots from each position in sequence and then repeating the sequence. The *high contextual interference* group followed a serial schedule by taking one shot from each position in sequence and then repeating the sequence six times.

On the day after the end of practice, each group performed three transfer tests: a twelve-trial blocked schedule for three of the practice positions; a twelve-trial serial schedule for the same three positions; and a ten-trial free-throw test (the free-throw line was one of the six practiced positions). All three groups improved their shooting performance during practice, but they did not differ from each other at the end of practice. However, the blocked-serial practice schedule group performed better than the other two groups on all three tests. In addition, low amounts of contextual interference during practice led to poor adaptation to change. The blocked practice group maintained their end-of-practice performance level for the blocked and free-throw tests, but their performance on the serial test decreased to the level of their first day of practice.

interference in practice schedules. First, higher levels of contextual interference will be optimal for learning skills with the lowest levels of difficulty, but less optimal for skills with the highest levels of difficulty. Second, for beginners, or those with low skill levels, lower levels of contextual interference will be optimal; while higher levels of contextual interference will be more effective for more skilled individuals. Although these predictions fit the model the authors created, we need empirical evidence to determine how well they apply to specific motor skill learning situations.

Implications for the Practitioner

Given the inconclusive nature of our present knowledge about the specific factors that limit the generalization of the effect of contextual interference on skill learning, what should the practitioner do? To answer this, refer to figure 16.3. It is important to keep in mind that our present knowledge is different for the top and bottom portions of the continuum in this figure. In terms of the top half, we know that moderate and high amounts of contextual interference generally produce better learning of skill variations than low amounts. However, the bottom half of the figure remains unresolved in terms of the amount of contextual interference specific practice schedules produce when they are used for the learning of specific skill variations. As a result, view the continuum in figure 16.3 as representing a generic relationship between the various practice schedules and the amount of contextual interference each produces.

For the practitioner, when several variations of a skill must be learned, the best course of action is to select a practice schedule that should produce a moderate to high amount of contextual interference (according to figure 16.3). But he or she should be prepared to modify the schedule after practice begins in order to accommodate individuals who do not respond well to the practice schedule. For example, some individuals may require a practice schedule that produces a lower amount of contextual interference, such as a blocked schedule, until they acquire the basic movement patterns of the skill variations. However, it is important that the practitioner base any practice schedule modification on performance difficulties evident from retention or transfer tests rather than on those from practice sessions.

ACCOUNTING FOR THE CONTEXTUAL INTERFERENCE EFFECT

An important question that remains unanswered is this: Why does the contextual interference effect occur? Two hypotheses predominate the several accounts for this effect. One is the *elaboration hypothesis;* the other is known as the *action plan reconstruction hypothesis.* We will consider each briefly in the following sections.

The Elaboration Hypothesis

In the experiment that first showed the contextual interference effect for learning motor skills, Shea and Morgan (1979) proposed that the effect is related to the *elaboration of the memory representation* of each of the skill variations that a learner is practicing.[1] During random practice, a person engages in more memory storage and retrieval-related strategies, as well as more different strategies, than an individual who practices according to a blocked schedule. Also, because in a random practice schedule the person retains in working memory all the skill variations he or she is practicing, the person can compare and contrast the variations so that each becomes distinct from the other. The result of engaging in these cognitive activities during practice is that the learner develops and stores a more elaborate memory representation for the skills that he or she then can access more readily during a test.

The Action Plan Reconstruction Hypothesis

An alternative hypothesis, by Lee and Magill (1985), stated that high amounts of contextual interference benefit learning because the interference requires a person to more actively reconstruct an action plan on the next practice trial for a particular skill variation. This reconstruction is necessary because the person has partially or completely forgotten the action plan he or she developed for the previous practice trial for that skill variation. The forgetting was due to the interference caused by the intervening practice trials of the other skill variations. In contrast, the person following a blocked practice schedule can use the same or slightly alter the action plan he or she used on the previous trial.

The following example illustrates how these different practice schedules would require different types of action plan activity. If you must add a long set of numbers and then you are immediately asked to do the same problem again, you probably will not re-add the numbers, but will simply remember and repeat only the answer. But, if your addition task requires you to add several additional lists of numbers before you are given the first list again, you probably will have forgotten the solution to that problem and therefore will have to add the same numbers again. The intervening problem-solving activity requires you to re-solve a problem you have solved already.

Lee and Magill hypothesized that the high contextual interference practice condition is like the addition situation in which there are several other problems to solve before you see the first problem again. When a learner practices a motor skill, the interference created by the practice trials between two trials of the same skill variation causes the person to forget much of the action plan he or she developed for the first trial. As a result, the learner must reconstruct and modify that plan to attempt the skill on the next trial. On the other hand, the blocked practice schedule is like the addition problem in which the next trial follows immediately, and it is easy to remember the solution and therefore be successful on the next trial.

In the motor learning context, *high contextual interference conditions require learners to engage more actively in problem-solving activity* during practice. Although this activity typically leads learners to perform more poorly during practice than they would with a low contextual interference schedule, this short-term performance deficit becomes a long-term benefit, because it leads to better retention and transfer test performance.

Research Supports Both Hypotheses

Much research is needed to determine which of the two hypotheses best accounts for the contextual interference effect. In his review of the research literature, Brady (1998) discussed several studies

[1]Shea and Zimny (1983) developed a more formal version of the elaboration hypothesis.

that provide support for each hypothesis. Since the publication of that review, Immink and Wright (2001) presented empirical evidence supporting roles for both explanations. Based on the results of two experiments, they concluded that random practice not only promotes a refinement of motor programming processes (i.e., the action plan reconstruction hypothesis), it also enhances the strength and quality of the memory representation of the movement variations learned during practice (i.e., the elaboration hypothesis). Results such as these indicate that rather than being competing explanations for the contextual interference effect, the elaboration and reconstruction hypotheses are complementary.

Examination of the brain activity associated with blocked and random practice has also provided support for both explanations of the CI effect. For example, Cross, Schmitt, and Grafton (2007) found that learners who practiced a finger-sequencing task in a random order used longer study times prior to movement execution than learners who practiced in a blocked order. In addition, fMRI data revealed group differences in the brain areas known to be involved in movement preparation, leading them to suggest that random practice engaged movement preparation processes to a greater extent than blocked practice. Cohen, Cross, Wymbs, and Grafton (2009) subsequently used TMS to the motor cortex (M1) ipsilateral to the limb used to perform the learning task to perturb movement preparation processes during random practice. Retention performance one day later revealed poorer performance for participants who had practiced randomly with TMS than those who had practiced randomly without TMS. Again, these findings highlight the important contribution that preparatory processes make to learning and they provide indirect support for the action plan reconstruction hypothesis, which maintains that the CI effect is a function of the more difficult action planning that accompanies random practice.

In contrast to the above-mentioned studies, Lin, Fisher, Winstein, Wu, and Gordon (2008) and Lin, Winstein, Fisher, and Wu (2010) found that TMS applied to the M1 area contralateral to the limb used to perform the task, immediately after feedback for the trial was presented, eliminated the random-practice advantage in retention relative to blocked practice. These findings provide indirect support for the elaboration hypothesis because they reveal the importance of post-trial processing (where comparisons with other task variations would be made) to the CI effect. Taken all together, these neurophysiological studies suggest that the CI effect involves specific processing activities that learners engage in before and after each practice attempt.

Regardless of which hypothesis, or combination of hypotheses, accounts for the contextual interference effect, three important learner-related characteristics are associated with the effect. One is that *higher levels of contextual interference involve greater attention demands during practice* than lower levels, which is predicted by both the elaboration and reconstruction hypotheses. Li and Wright (2000) provided evidence of the greater attention demands for random compared to blocked practice by requiring participants to perform a secondary choice reaction-time task between practice trials and just before initiating their movements for a practice trial. These results help explain earlier results that showed higher physiological activation associated with higher levels of contextual interference (e.g., Husak, Cohen, & Schandler, 1991). The second characteristic, which we discussed earlier, was identified by Simon and Bjork (2001): *People who practice according to a blocked schedule tend to overestimate how well they are learning during practice.* The third characteristic is that *higher levels of contextual interference encourage people to make more errors* and so they may encourage greater refinement in the process of detecting and correcting errors that is so central to learning (e.g., Broadbent et al., 2017).

PRACTICE SPECIFICITY

In chapter 13, you learned that the amount of transfer of learning is a function of the degree of similarity between practice and test characteristics, which means that the best learning will occur when practice characteristics are the same as those of the test. However, this conclusion appears to be at odds with the discussion so far in the present chapter in which practice variability is presented as an important practice characteristic that is critical for successful future test performance. How, then, can both of these seemingly contradictory principles be correct? As you will see in the following sections, we have discussed various aspects of practice specificity which can be seen as distinct, although related to the benefits of practice variability.

The **specificity of practice hypothesis** is one of the oldest principles of human learning. Its origins can be traced back to the early 1900s when Thorndike (1914; Thorndike & Woodworth, 1901) presented the *identical elements theory* to explain why positive transfer occurs between two skills or skill learning situations. Briefly, this theory, which was discussed in chapter 13, proposed that the more "elements" (i.e., physical and mental characteristics) two skills or situations have in common, the greater the amount of transfer of learning or performance. The practice specificity hypothesis can also be linked to our discussion in chapter 3 about motor abilities where we considered the specificity of motor abilities hypothesis, which was attributed to Franklin Henry in the 1960s (e.g., Henry, 1961a, 1961b). Henry's hypothesis proposed that motor abilities are independent and task specific and that individuals have varying levels of many motor abilities. In addition, the relationship between performances by a person on two different skills would depend on the degree of common abilities between the skills. Finally, in chapter 12 in the discussion of various performer and performance characteristics that change during the course of learning a skill, you read about the influence of practice specificity in skill learning for a performer-related characteristic that does not change.

Researchers generally agree that sufficient research evidence exists to support the practice specificity hypothesis for at least three characteristics of motor skill learning and performance. We have discussed each of these in previous chapters, but we will consider them here as they apply to the organization of practice. After discussing each characteristic, we will address the question of how the practice specificity hypothesis relates to the practice variability hypothesis and the contextual interference effect.

Practice Specificity for Sensory/Perceptual Characteristics

As you read in chapter 12, research by Proteau and his colleagues in Canada (e.g., Proteau, 1992) demonstrated that motor skill learning is *specific to the sources of sensory/perceptual information available during practice*. The specific focus of their research has been on the role of vision and proprioception as the sensory/perceptual information available during the performance of a skill. That focus was motivated by views that emphasized visual sensory feedback is important in the early stage of learning but is diminished in its importance with practice and eventually is replaced by proprioceptive feedback in its importance for performance (e.g., Fleishman's view on the relationship of motor abilities to skill learning, which was discussed in chapter 3, and the Schmidt schema theory's hypothesized changes over the course of skill learning, which was discussed in chapter 12).

In contrast to views promoting the idea that visual feedback becomes less important as learning continues Proteau's research consistently showed the opposite effect: If a person has vision available during practice, vision remains an essential source of sensory information throughout the stages of learning. In fact, performance typically decreases when vision is not available during a retention or transfer test. Several examples of this research were presented in chapter 12 in which researchers showed support for Proteau's hypothesis for the learning of a variety of motor skills, such as manual aiming, power lifting, and walking. In addition to those studies, a more recent one by Moradi, Movahedi, and Salehi (2014) found similar vision effects for learning a basketball free-throw shooting skill.

An especially notable finding in some of those studies is that as the amount of practice with vision increases, the need for vision on a subsequent

specificity of practice hypothesis the view that motor skill learning is influenced by practice condition characteristics, especially the sensory/perceptual information available, performance context characteristics, and cognitive processes involved.

A CLOSER LOOK

Brain Region Activity Shows Context Specificity for Learning Rhythmic Timing

A study by Jantzen, Steinberg, and Kelso (2005) investigated brain areas involved in the learning and performance of a rhythmic timing task. Their results demonstrated practice specificity effects by showing a context-dependent network of brain regions activated according to whether a visual or auditory signal guided the practice of a timing task that required movements that were synchronized (in music terms, this means move with the beat) or syncopated (move off the beat) with the signal.

The rhythmic timing task: A visual or auditory metronome paced participants to coordinate index finger and thumb opposition (i.e., moving the index finger to touch the thumb) at a continuous rate of 1.25 movements per second.

Visual metronome: A red dot appeared on a computer monitor

Auditory metronome: A tone heard through headphones

Synchronized movement trials: Touch the thumb at the same time the signal occurred (continue movement at same rhythm after signal stopped; i.e., transfer test)

Syncopated movement trials: Touch the thumb midway between the signals (continue movement at same rhythm after signal stopped; i.e., transfer test)

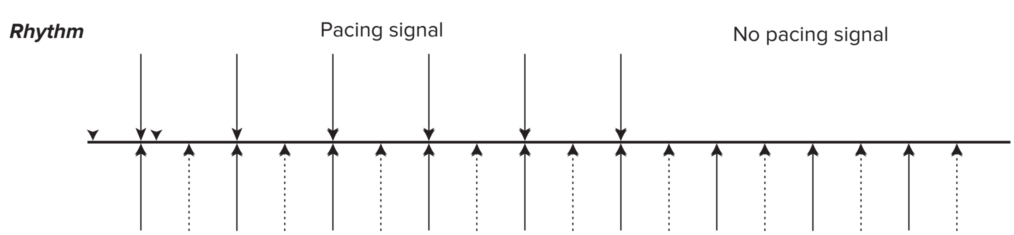
Brain activity assessment: Each participant was placed in a supine position in an MRI scanner, the head fixed with a vacuum pillow. The scanner had fMRI capabilities.

Results:

Timing performance with and without pacing signal: Participants achieved the required movement rates for both the synchronized and syncopated coordination modes.

Brain activity: When the visual signal paced performance, brain activity involved areas typically involved in the integration of visual and motor information and the translation of visual sensory information into motor output. These areas were the middle temporal lobe, bilateral superior parietal lobe, and ventral premotor cortex. What is more interesting is that these regions remained active when the participants performed the movements without the visual pacing signal present. Activity in these areas was absent when the auditory signal paced performance.

Conclusion: The brain activity results support the practice specificity hypothesis proposed by Proteau (e.g., Proteau, 1992) that motor skill learning is specific to the sources of sensory/perceptual information available during practice. Practice with the visual signal activated brain areas specific to visually guided coordination even when the visual signal did not appear during the transfer trials.



Synchronized movement: solid arrows
Syncopated movement: dotted arrows

retention or transfer test also increases (Proteau, Tremblay, & DeJaeger, 1998). Evidence has indicated that this increased need for vision during retention and transfer is not because the availability of vision during practice prevented the processing of proprioceptive information, but because practice with vision encourages people to prefer to use the same motor plan to perform the skill without vision (on transfer tests) as they used during practice with vision (Mackrous & Proteau, 2007).

A different approach to the practice specificity effect of vision during learning involved the use of observational learning (Osman, Bird, & Heyes, 2005). The experiment involved participants learning an eight-item sequence in a serial reaction time task on a computer keyboard. After observing a skilled model demonstrate the sequence with the right hand, participants then practiced the task with their right hand and then their left hand. Results showed that the observation of the model influenced performance only with the right hand.

Neurophysiological evidence also demonstrates the practice specificity effect for sensory characteristics. For example, in a study in which researchers used fMRI to observe the brain activity associated with learning a timing skill (Jantzen, Steinberg, & Kelso, 2005), participants practiced tapping their thumb with the index finger to a specific rhythm that was paced by either a visual or auditory metronome. Eventually the metronome stopped but the participants continued to tap the rhythm. The brain areas active during practice with the visual metronome remained active during the tapping without the visual metronome. These brain areas were those in the visual dorsal stream, which we discussed in chapter 6 as the vision-for-action visual system.

Practice Specificity for Performance Context Characteristics

You read in chapter 10 that the encoding specificity principle is a well-established characteristic of memory. This principle identifies the strong association between encoding and retrieval contexts for memory performance by stating that the more a memory test (i.e., retrieval) context resembles the practice (i.e., encoding) context, the better will be the retention performance. Recall that an important part of the performance context issue is the distinction between intentional and incidental remembering. *Intentional* remembering refers to when you must remember specified characteristics of an environmental context, whereas *incidental* remembering refers to the remembering of related but nonessential parts of the context. For example, you are practicing the return of a serve in tennis, and you are told to estimate and report the ball speed for a serve. If you are then asked to report not only the ball speed but also the location in the service court where the ball landed, you will likely be able to report both, even though you were not instructed to give attention to or remember the ball's landing location. In this example, reporting the ball speed represents intentional remembering; reporting the ball's landing location represents incidental remembering.

Research by David Wright and his colleagues extended the performance context aspect of the encoding specificity principle to motor skill learning situations. Their research consistently demonstrated that characteristics of a practice environmental context that are not parts of the actual skill to be learned also get learned (e.g., Wright & Shea, 1991, 1994). In these experiments participants typically learned three- or four-digit sequences of key presses on a computer keyboard. Participants saw specific sequences of the numeral keys displayed on the computer monitor as the intentional items they needed to learn. In addition, each sequence was color coded, which created an association between a number sequence and its color. Participants were not told about the color-coding feature, which means that color was an incidental part of the performance context; it was not a part of the skill that the participants were told to learn. However, their performance was better on the transfer test when they were shown both the number sequence (the intentional items to be learned) together with the associated color coding (the incidental part of the practice environment) than when they were shown the same number sequences with different colors. Thus they learned not only the number sequences that they were told to learn, but also the colors associated with the sequences. Interestingly, in interviews after the experiment, participants indicated that they were unaware of the number-color relationship.

What is evident from the research investigating performance contexts is that people *learn more about the context than they are explicitly instructed to learn*. Parts of the environmental context in which a skill is practiced get included in what people learn. When these incidental parts of the context are available during a test, they serve as cues, or aids, to help retrieve the memory representation of the learned skill. Conversely, when these incidental environmental context features are not available during the test environment, performance is diminished. Examples of this effect include the use of mirrors in dance studios and weight training rooms. Because the mirrors are part of the practice environment, the visual feedback received from them becomes part of what is learned. When the mirrors are not available, as would occur in a dance performance on a stage or in a weight lifting competition, performance of these activities would be poorer than it would be with the mirrors present.

According to Shea and Wright (1995), the decision of which specific skill to perform in a situation and the speed of its selection depend on the strength of the relationship between intentional and incidental features in the performance environment. The implication for skill training is to include as many features of a test environmental context as possible in the practice environmental context. For example, if a goal of gait training in physical therapy is for the patient to be able to walk in a crowded mall as part of his or her daily living activities, then therapy sessions should include supervised walking in a crowded mall when the therapist determines that the patient can engage in this type of activity. In terms of its application to sports situations, the learning of the incidental parts of players' environmental context during practice and competitions leads to the "home field advantage" that is commonly observed in sports competitions. This means that parts of the performance context in the "home field" are more familiar to the home team because they learned those parts when they practiced in that context. Thus, they have learned important context cues that aid their performance, even though they never practiced intentionally learning those cues.

Practice Specificity for Cognitive Processing Characteristics

In chapter 13, one of the explanations of positive transfer considered the similarity of the cognitive processes required by the skills or learning situations. According to the *transfer-appropriate processing theory*, the type of practice that is best when a person is learning a skill requires the same type of cognitive processing activity that will be required in a transfer test, regardless of the physical similarity between the practice and test skills and situations. For example, if the test situation will require rapid decision making, practice should consist of activities that require rapid decision making. A good example of this type of rapid decision-making situation is when a soccer player dribbles the ball down the field and sees that a defender will soon confront him or her, the player must decide very quickly whether to continue dribbling, or to pass the ball to a teammate. One of the reasons for this relationship is that the cognitive processing that is a part of practice becomes a part of what is learned. As a result, the cognitive processing demands of a practice situation are a practice-specific aspect of skill learning.

An experiment by Pellecchia (2005) provides a good example of the practice specificity of cognitive demands during skill learning. Participants practiced standing still for 30 sec on a balance platform on which the surface was covered with a foam pad to reduce somatosensory feedback and increase reliance on vestibular and visual feedback. Two groups of participants practiced only the balance skill (single-task training) or that skill together with a cognitive secondary task (dual-task training), which was counting backward by threes from a three-digit number that was randomly presented on each trial. Results showed that when both groups performed a transfer test one week later with the dual-task condition, the single-task training group showed an increase in postural sway, while the dual-task training group did not, which demonstrated that the cognitive processing demands imposed by the dual-task training became a part of what was learned. The similarity between the cognitive processing demands during practice and the test resulted in successful performance on the dual-task transfer test one week later.

A more recent study by Song and Bédard (2015) showed particularly strong context specificity effects during dual-task practice. When participants concurrently practiced an aiming task and a secondary discrimination task, they retained the accuracy of the aiming movement when it was tested later with the secondary task; but their performance regressed to baseline levels when they were tested without the secondary task, despite the additional attentional capacity that would have been available without the secondary task.

Relating the Practice Variability and Specificity Hypotheses

Although the practice specificity hypothesis may appear to be at odds with the practice variability hypothesis, research indicates that each hypothesis may pertain to specific aspects of the practice context. The *practice variability hypothesis* explains the retention and transfer benefit associated with practicing multiple variations of a skill. On the other hand, the *practice specificity hypothesis* explains why retention and transfer performance tend to be better when the practice and test contexts are similar relative to (a) the sensory/perceptual information available, (b) the environmental context in which the skill is performed, and (c) the cognitive processing requirements.

Also, it is worth noting that for many contextual interference studies, the higher contextual interference during practice was more similar to the test situation than was the lower contextual interference practice condition. This is not to say that the contextual interference effect is a practice specificity effect, but that there are situations in which the relationship between the practice and test conditions are similar.

Especial skills. A new phenomenon, referred to as *especial skills*, has added another dimension to our understanding of practice specificity and variability. The especial skill effect was first demonstrated by Keetch, Schmidt, Lee, and Young (2005) in an experiment in which skilled basketball players performed shots at various distances from the basket. The results showed that they consistently shot more accurately from the foul line than would be predicted from their shooting accuracy at distances shorter than 9, 11, and 13 ft and longer than 17, 19, and 21 ft the foul line distance. The effect occurred even when the lines of the court were covered to control for the possible effects of the incidental learning the players had experienced throughout their careers. The effect has been replicated with skilled baseball pitchers, who pitched more accurately from the regulation pitching distance (60.5 ft) than would have been predicted from their accuracy at distances shorter than and longer than the regulation distance (Simons, Wilson, Wilson, & Theall, 2009). It has also been replicated with skilled archers, who shot more accurately from the regulation distance (18 m) than would have been predicted from their accuracy at shorter and longer distances (Nabavinik, Abaszadeh, Mehranmanesh, & Rosenbaum, 2018).

These findings are intriguing because they support tenets of the practice variability and practice specificity hypotheses, yet they cannot be accounted for completely by either hypothesis. The ability to perform accurately from various distances, even though accuracy decreased systematically as distance from the target increased, supports the postulate in Schmidt's (1975) schema theory of a generalizable memory representation for a class of movements. However, schema theory cannot account for why performance at one specific distance—a distance that would be practiced much more extensively than any other distances—would be so much better than predicted from performance at the other distances. The *especial* performance at the regulation distance is more consistent with the specificity of practice hypothesis. Despite the uncertainty that surrounds the locus of the especial skill effect, research on this intriguing phenomenon has the potential to greatly enhance our understanding of the role of specificity and variability in motor skill learning (Breslin, Schmidt, & Lee, 2012).

SUMMARY

Variations of movement and context experiences are important ingredients for practice conditions that increase a person's capability to perform the practiced skill successfully and to adapt to conditions he or she has not experienced previously.

- Research evidence shows that *variable practice* leads to superior retention and transfer test performance when compared to *constant practice.*

- To determine the characteristics of a test context that should be varied in practice, identify the regulatory and nonregulatory conditions of the test context. Which of these conditions should be varied in practice depends on whether the skill is a closed or open skill.
- An important practice condition concern is how to organize the variety of experiences for a practice session, unit of instruction, or therapy protocol. The *contextual interference effect* provides a basis for scheduling these experiences during practice.
- The contextual interference effect occurs when practice schedules that include higher amounts of contextual interference (e.g., random practice schedules) lead to better learning than those that include low amounts (e.g., blocked practice schedules).
- Research evidence indicates that the contextual interference effect applies to beginners as well as to skilled performers and to laboratory skills and a wide range of sports and everyday skills; however, the effect is not applicable to the learning of all motor skills or to all learning situations. Researchers have not identified the specific factors that limit the generalization of the contextual interference effect.
- Two hypotheses predominate as explanations for why the contextual interference effect occurs: the *elaboration hypothesis* and the *action plan reconstruction hypothesis.*
- The practice specificity hypothesis differs from the practice variability hypothesis and contextual interference effect by proposing that the best transfer test performance will result from practice situations in which characteristics are the most similar to those of the transfer test. Research has shown that the following three characteristics of motor skill learning and performance support this hypothesis:
  - ► The sources of sensory/perceptual information available during practice
  - ► Performance context characteristics
  - ► Cognitive processing characteristics
- Although the practice specificity hypothesis appears to contradict the predictions of the practice variability hypothesis, research indicates that each hypothesis relates to different practice and test characteristics. The practice specificity hypothesis relates primarily to certain characteristics of the practice and test context, whereas the practice variability hypothesis relates specifically to the movement characteristics of the skill that is learned.

POINTS FOR THE PRACTITIONER

- The goal of practice sessions should be to provide opportunities for people to develop the capability to perform activities that will require the use of the skills being practiced and to achieve the action goals of those activities wherever they occur.
- Practice conditions that encourage people to make errors are beneficial for helping people to learn skills in a way that maximizes their capability to perform the skills in a variety of contexts and situations.
- When teaching a motor skill that will require the person to adapt to environmental context conditions or situations that the person hasn't experienced before, design practice conditions that will require the person to perform the skills in as many different environmental context conditions and situations as possible can be created.
- When teaching a motor skill that will require performance in environmental contexts in which the regulatory conditions will not change, such as shooting free throws in basketball or ascending or descending a set of stairs at home, design practice conditions that will require the person to perform the skills in the specific environmental context in which he or she will be required to perform the skill, but provide experiences with as many nonregulatory conditions and situations as possible.
- When organizing practice sessions for learning multiple skills or variations of a skill, provide opportunities to practice all the skills or variations in each session. When possible, arrange to have the skills in each session practiced in a random arrangement.
- If the test conditions for a skill that a person is learning will not allow visual feedback, develop practice conditions that do not provide visual feedback, such as the use of mirrors, especially

for practice sessions that immediately precede the test situation.

- Include in a practice situation as many of the environmental context features of an upcoming test environment as possible.

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STUDY QUESTIONS

1. What is meant by the term *practice variability* and why is it important for skill learning?
2. Give an example of how you would implement practice variability for (a) a closed skill without intertrial variability, (b) a closed skill with intertrial variability, (c) an open skill.
3. (a) Define the terms *contextual interference* and the *contextual interference effect* as they relate to the learning and performance of multiple skills or multiple variations of a skill.

(b) Discuss how the amount of contextual interference relates to the types of practice schedules that could be developed for situations in which people must learn multiple skills or multiple variations of a skill.

4. Describe four practice schedules that involve different amounts of contextual interference and locate each on a continuum that ranges from low to high amounts of contextual interference.
5. Describe an example that illustrates how you would implement an appropriate amount of contextual interference into the practice schedule for (a) a novice learning a skill and (b) a skilled person.
6. What are two reasons researchers have proposed for the benefits of contextual interference for motor skill learning?
7. Discuss (a) the practice specificity hypothesis in terms of its application to motor skill learning; and (b) how it relates to the practice variability hypothesis.

Specific Application Problem:
In your place of employment in your future profession, your supervisor has asked you to develop a schedule of activities for the people for whom you are responsible (e.g., students, athletes, patients) to help them improve their capability to perform at least three variations of a motor skill. You have a specified number of sessions in which you can work with these people. Describe the specific characteristics of this situation and specify the skills to be learned and the schedule you would design. Justify your plan to your supervisor in terms of why you would expect it to yield the best possible results.