The Amount and Distribution of Practice

CHAPTER **17**

Concept: The amount of practice and the spacing or distribution of that practice can affect both practice performance and the learning of motor skills.

After completing this chapter, you will be able to

- Define *overlearning* in terms of how it relates to the decision about the amount of practice time needed to learn motor skills
- Describe how an overlearning practice strategy influences the learning of procedural skills and dynamic balance skills
- Discuss the relationship between overlearning and other practice condition variables
- Describe how the concept of practice distribution is related to the intertrial interval and to the length and distribution of practice sessions
- Discuss evidence supporting the benefit for distributed practice of the distribution of practice sessions and possible reasons for this benefit
- Compare and contrast massed and distributed intertrial interval schedules for discrete and continuous motor skills
- Describe how to implement knowledge of massed and distributed practice in various skill learning situations

APPLICATION

Teachers, coaches, and therapists must make important decisions about the amount of practice people should engage in, as well as how much time to devote to various activities within and across practice sessions within the total amount of practice time available. In terms of the amount of practice needed to learn a skill, the conventional wisdom seems to be that the more practice a person has, the better his or her performance will be in some future situation. Consider some examples. It seems likely that a dance teacher would encourage a dancer who was a bit tentative in certain parts of a routine to spend as much time as possible going over the routine repeatedly in practice. A golf instructor would probably try to help a person be more successful with a certain shot by encouraging the person to spend as much time as possible on the practice range. Our experiences in situations like these lead us to accept the view that for improving performance "more practice is better." But ironically, although this view of practice seems logical, research indicates that it is not always the best alternative. For example, as you saw in chapter 16 the same amount of practice can yield different learning results when practice follows different practice organization schedules. And, in chapter 15 you saw examples of the same amount of practice resulting in different learning outcomes depending on the frequency of augmented feedback. You will see another example of this type of effect in the Discussion section that follows.

After having determined the amount of practice time people need to learn a motor skill, the practitioner needs to determine how much time to devote to various activities within and across practice sessions.

He or she must determine the amount of time to devote to each activity in a session, the amount of rest between activities within a session, the length of each session, and the amount of time between sessions.

If you are a physical education teacher organizing a volleyball unit, you need to determine how much time you should devote in each class period to working on the various skills, drills, and other activities that you plan to include. If you have determined the total amount of practice time you want to devote to a given activity in the unit, and you know how many class periods you will have in the unit, you will know how much time you need to spend in each class period on that activity.

Similarly, if you are an athletic trainer or a physical or occupational therapist, you need to determine how much time an athlete or a patient will spend on each activity within a session, how much rest time you should allow between activities in a session, when the next session should be, and so on. You also may need to instruct the person concerning how to arrange his or her time schedule to do prescribed activities at home.

Application Problem to Solve Select a motor skill that you perform well for recreational or sports purposes and for which you received professional instruction. Think back to your early experiences when you practiced the skill with your instructor. Describe as best as you can remember how much practice you engaged in until you performed the skill at a proficient level. And describe the characteristics of the practice sessions in which you were involved with your instructor. How would you do these things in the same way as or differently from your experiences, and why would you keep things the same or change them?

Or recall an experience you had in physical rehabilitation with an athletic trainer or a physical or occupational therapist. Describe as best as you can remember the amount of rehab/therapy you experienced until you could perform the skill at a desired level. And describe the characteristics of the rehab/therapy sessions in which you were involved. How would you do these things similarly to or differently from your experiences, and why would you keep things the same or change them?

DISCUSSION

The amount of practice a person devotes to a skill is critical for learning motor skills. This is especially the case when the person has the attaining of expertise as a goal. As we discussed in chapter 12, the impressive work by Ericsson and others has shown that expertise in any field is the result of intense practice for a minimum of ten years (Ericsson et al., 1993). Clearly, for achieving expertise, more practice is better than less. However, the amount of practice required to attain expertise is not our focus here. Instead, we will focus on the amount of practice a person needs to ensure achieving a specific performance goal associated with a specific period of practice.

There are many situations in which it is important to determine the amount of practice people should experience to achieve specific skill performance goals. Although limitations may exist in many of these situations in terms of the amount of time available for practice, the need to determine the amount of practice required remains. For example, a physical education teacher needs to determine the number of classes within a unit to devote to learning a specific activity. In sports settings, the amount of practice time available is typically restricted by a season's schedule or by rules established by professional associations. And, in rehabilitation contexts, the amount of time available for therapy is typically restricted by health care provider agencies.

As we address the issue of optimal amounts of practice, we will limit our discussion to these types of situations and establish some guidelines for the effective and efficient use of available practice time. As suggested by the examples we just considered, this limited focus is particularly relevant to those involved in settings that impose strict practice time limitations on teachers, coaches, and therapists.

OVERLEARNING AND LEARNING MOTOR SKILLS

Researchers historically have investigated the relationship between the amount of practice and the achievement of specific performance goals within the topic of *overlearning*. **Overlearning** is the continuation of practice beyond the amount needed to achieve a certain performance criterion. A teacher, coach, or therapist implements an overlearning strategy by establishing a specific performance criterion, such as a specific accuracy average for throwing a certain number of balls at a target. The teacher then requires students to achieve that performance criterion during class, record the number of trials it took for the student to reach that goal, and then require a specified number of additional practice trials, to implement an overlearning practice condition.

From a theoretical perspective, the assigning of extra practice has merit. According to a motor program–based motor learning theory, extra practice helps strengthen the generalized motor program and response schema for the skill a person is learning, so that the person can call it into action more readily when necessary. From a dynamical systems theory perspective, extra practice is a means by which a learner increases the stability of the coordination and control characteristics in the performance of the skill.

Driskell, Willis, and Copper (1992) reviewed and analyzed fifteen research studies that investigated several hypotheses related to overlearning. The first notable point about this review is that the issue of overlearning has not generated a great deal of research over the years. The fifteen studies covered research articles published from 1929 to 1982. However, these studies involved almost 4,000 subjects, which gives us a good basis for discerning the influence of overlearning on skill acquisition and how various factors influence overlearning. The results of this review indicated that for motor skill learning, overlearning has a positive influence on retention performance. And when extra practice of 50 to 200 percent was analyzed, the higher percentages resulted in relatively proportionate higher retention test performance.

Although the Driskell et al. (1992) review provides a comprehensive overview of overlearning as it relates to skill acquisition, it does not evaluate effects related to specific types of motor skills. Because motor learning research has shown that certain types of skills demonstrate some distinct characteristics with regards to overlearning, we will consider three examples in the following sections.

The Overlearning Strategy for Learning Procedural Skills

Procedural skills constitute one type of motor skill particularly well suited to deriving benefits from an overlearning practice strategy. A procedural skill is an interesting combination of cognitive and motor components. Although this term was not included in chapter 1 in the discussion of types of skills, it is a relatively common term used in the training and functional skills literature. It typically requires a person to perform a series of movements that individually are relatively easy to execute. However, to accomplish the total task, the performer must know which movements to make and in what order. These types of skills are especially common in occupational, industrial, and military settings. For example, people perform procedural skills when their jobs require them to put together the components of a circuit board for a computer, or type from a written text.

A common problem with procedural skills is that people tend to forget what to do to carry out the entire procedure. This is particularly characteristic of procedural skills that they do not perform routinely every day. For example, several years ago, the U.S. Army was interested in improving the performance of soldiers for a procedural skill that involved assembling and disassembling machine guns. This skill was important to study because soldiers typically learned it in a short training period, but did not perform it again until sometime after training; it was not a routine part of their daily duties. The problem was that when they performed a later test on this skill, the soldiers typically showed

overlearning practice that continues beyond the amount needed to achieve a certain performance criterion.

a large decrement in performance, compared to how they had performed at the end of training. To overcome this problem, researchers for the U.S. Army Research Institute (Schendel & Hagman, 1982) proposed that an overlearning training strategy (which they referred to as *overtraining*) would be effective for decreasing the amount the soldiers forgot about the procedure.

The researchers compared two forms of overtraining to a no-overtraining situation. One form was an "immediate" overtraining condition, which required soldiers to perform 100 percent more trials than they required to achieve a performance criterion of one correct assembly/disassembly trial. The second overtraining condition also involved an additional 100 percent more practice trials, but these trials were administered as "refresher" training midway through the eight-week retention interval used for all subjects. Results showed that both of these overtraining groups performed better than the no-overtraining control group on the retention test, which required the soldiers to practice until they were again able to assemble and disassemble the gun correctly on a trial. However, the two overtraining groups did not differ from each other in the number of trials it took to retrain to the criterion performance of one correct trial.

Based on the results of this experiment, the authors recommended the immediate overtraining procedure, because it was more cost- and time-effective. Because the trainees were already in the training session, it would take less time and money to have them engage in additional practice there than to bring them back several weeks later for a refresher training session.

The Overlearning Strategy for Learning Dynamic Balance Skills

In an experiment that involved learning a skill that has less of a cognitive component than the gun assembly/disassembly skill, Melnick (1971) investigated the use of overlearning for a dynamic balance skill. This experiment continues to be the only one reported in the research literature that involves the overlearning of dynamic balance skills. In addition to addressing the question of whether practice beyond the amount the learner needed to achieve a performance criterion was beneficial, Melnick asked whether there was an optimal amount of extra practice. In this experiment, people practiced balancing on a stabilometer until they were able to achieve a performance criterion of being on balance 28 out of 50 sec. After achieving this criterion, each group was required to perform further trials in one of the following amounts: 0 percent (none), 50 percent, 100 percent, or 200 percent of the initial number of trials of practice. Then, all participants performed a retention test twice, one week and then one month after practice.

The results showed that all amounts of extra practice were beneficial. This means that all the groups that engaged in extra practice beyond what they needed to achieve the performance criterion performed better on the retention tests. More interesting, however, was the result that there was *a point of diminishing returns* for the amount of retention performance benefit in relation to the amount of extra practice. This effect can be seen in the results when the group that had 50 percent additional practice did as well on the retention tests as the groups that had 100 percent and 200 percent extra practice. So, although additional practice was beneficial, increasing the amount of additional practice beyond the 50 percent amount was not proportionally more beneficial to retention performance.

Supporting evidence for the lack of benefit for additional practice beyond a certain amount was reported by Kwakkel and Wagenaar (2002) for physical therapy sessions. Although this study did not focus on dynamic balance, it showed that providing additional physical therapy sessions each day during a five-day-per-week, twenty-week period did not result in additional benefits for stroke patients immediately after the onset of their stroke.

The Overlearning Strategy in a Physical Education Class

Researchers also have demonstrated the presence of the "diminishing returns" phenomenon for learning skills in physical education classes. A good example of this is an experiment by Goldberger and Gerney (1990). In a unit of instruction, fifth-grade boys and girls practiced several football skills. The goal of this unit was to help students improve their performance of these skills. To simplify matters, we will look only at the two-step football punt. One group practiced these skills according to a teacher-rotated format, in which the teacher divided the class into five subgroups and assigned each to one of five stations where they practiced a specified skill for 5 min. At the end of every 5 min, students rotated to a new station. Another group of students practiced according to a learner-rotated format: They received index cards describing what they needed to do at each station and then were told to use their 25 min efficiently to practice each skill. Everyone practiced like this for two class periods on two days. The next week, the students performed the skills in a test.

The results showed that the two groups differed in terms of the number of practice trials for this skill, but not in test performance. The teacher-rotated format group actually practiced the skill an average of 7 more trials than the learner-rotated format group. Students in the learner-rotated format group performed from 0 to 67 trials, whereas students in the teacher-rotated group performed from 0 to 87 trials. But there was no difference between the groups in the amount of improvement in their punting performance scores. The additional amount of practice induced by the teacher-rotated format did not yield an additional skill performance improvement benefit on the retention test. Thus, given the time constraints of the unit of instruction, the learner-rotated format was superior, because it provided more efficient use of the available practice time.

THE OVERLEARNING STRATEGY CAN LEAD TO POOR TEST PERFORMANCE

Although the overlearning strategy typically benefits skill learning, some evidence shows that in addition to the diminishing returns phenomenon, learning deficits may result from providing *too many* extra practice trials. For example, Shea and Kohl (1990) reported an experiment in which participants learned to push a handle with a specified amount of force (175N). One group practiced this skill for 85 trials. Another group also practiced this skill for 85 trials, but in addition practiced the same skill at four other force goals (125N, 150N, 200N, and 225N) for 51 trials each, for a total of 289 practice trials. A third group practiced the skill with the 175N goal force for 289 trials. One day later, all participants engaged in a retention test in which they performed the skill with the goal force of 175N for 10 trials.

The results showed that the group that practiced the 175N goal force for 289 trials had the poorest performance on the initial 5 trials of the retention test. In contrast, the group that practiced the variable goals performed best. Results for the group that practiced only 85 trials of the 175N goal fell between those of the two other groups. The differences between these groups were most distinct on the first retention trial. However, on the final 5 trials of the retention test, all three groups performed similarly. These results were replicated in another experiment by the same authors (Shea & Kohl, 1991).

Similarly, Travlos (1999) also reported that increasing the amount of practice beyond a certain number of trials resulted in poorer transfer test performance. In this experiment, participants attempted to learn the distance of a horizontal line by touching a digitizing tablet with a stylus at locations they estimated to be the beginning and end of the line. Although they could not see their movements, the participants received knowledge of results (KR) about their estimate in terms of the distance it deviated from the 8 in. criterion. Five groups experienced different amounts of practice: 42, 77, 102, 127, and 152 trials. At the end of practice, they performed a transfer test for five trials. This test required them to estimate the horizontal length of a 10 in. line. The results, which you can see in figure 17.1, showed that at the end of practice, all groups performed similarly. However, performance on the transfer test showed the influence of the different amounts of practice. Those who practiced the task for 77 and 102 trials performed the transfer test with less error than those who did other amounts of practice trials. The transfer test results also showed that 42 practice trials were too few, and that 127 and 152 trials were too many, which means that additional practice beyond 102 trials led to a decrement in transfer test performance rather than an enhancement of it.

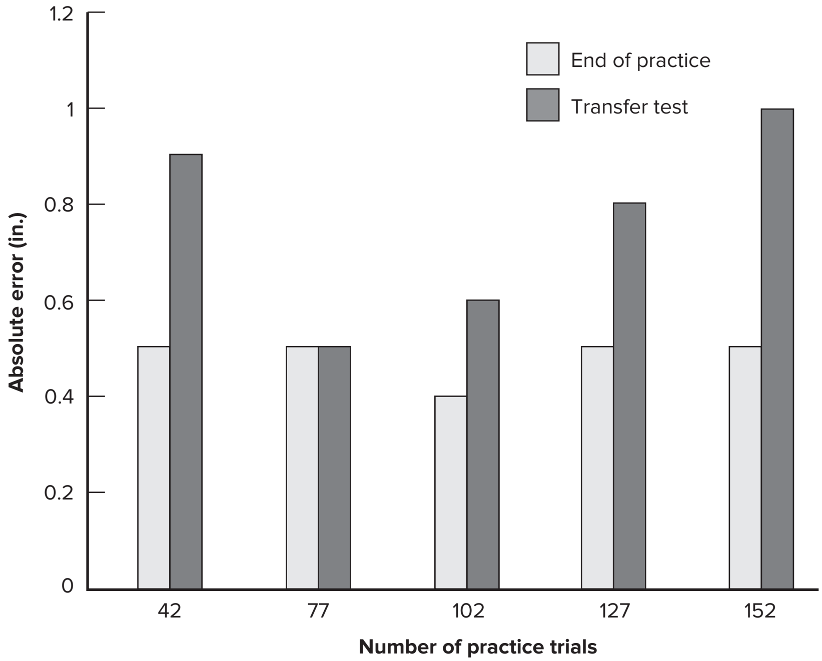

FIGURE 17.1 The results of the experiment by Travlos. Shown here is the amount of absolute error at the end of practice (gray bars) and for the transfer test (black bars) for five amounts of practice. *Source:* Travlos, A. K. (1999). More practice does not necessarily enhance transfer of learning: Evidence and interpretations. *Perceptual and Motor Skills, 89,* 1161–1175.

In a more recent study, Lee and colleagues (Lee, Bhatt, Liu, Wang, & Pai, 2018) reported that providing older adults (> 73 yrs old) with more than 24 trials of tripping practice on a treadmill did not improve incidence of falls, balance, or stability beyond the 24 trials.

The significance of the results reported in these experiments is that they run counter to what most people would expect, that the best way to improve performance is to increase the amount of practice. The research described in this section showed that the addition of more practice beyond a certain amount did not improve retention and transfer test performance.

Why would more practice lead to poorer retention and transfer test performance than less practice? One reason could be that because the skills practiced in these experiments were so simple, boredom became a problem after a certain amount of practice. As a result, the learners reduced the amount of attention the task required to improve performance. Or, as Lee, Swinnen, and Serrien (1994) described it, the learners ceased to engage in the amount of *cognitive effort* required to improve task performance.

A second explanation relates to both the motor program–based and the dynamical systems theories concerning the importance of *practice variability,* which you studied in chapter 16. According to these theories, continued practice of the same movement can result in a decreasing capability to remember the movement as well as to transfer to a movement variation, whereas the practice of variations of the movement results in enhancing the capability to remember and transfer to a related movement (note that these theories don't take into account the *especial skills* effect that was introduced in chapter 16). It is interesting to note in this regard that in the Shea and Kohl experiments, practice of criterion task variations resulted in better retention performance than the same amount of practice of the criterion task only. If these results were extended to performance on a transfer test, we would expect similar results.

OVERLEARNING AND OTHER PRACTICE VARIABLES

It can be useful for a learner to continue to practice a skill even though he or she can perform it successfully such practice increases the permanence of the person's capability to perform the skill at some future time. However, the research investigating the overlearning strategy has shown rather conclusively that *the amount of practice is not the critical variable influencing motor skill acquisition.* The amount of practice invariably interacts with some other practice-related variable to yield optimal skill learning. You have seen this interaction with a number of practice-related variables, such as the type and frequency of augmented feedback and the variability of practice where specific types and uses of these variables have shown better or worse learning with the same amount of practice. To establish an optimal learning environment, the instructor and/or learner also must take other practice condition characteristics into account. It is important to note that this perspective does not mean that the amount of practice is unimportant. It does mean that the amount of practice cannot be considered in isolation, but in terms of its interaction with other practice condition variables.

THE DISTRIBUTION OF PRACTICE

Practice distribution (sometimes referred to as the spacing of practice) has been a popular topic for research in motor learning for many years. The most popular era for this study extended from the 1930s through the 1950s, when practice distribution was seen as a way to test learning theories popular at that time. However, researchers have continued to investigate practice distribution issues because of its relevance to applied settings in a variety of contexts.

One of the issues that was the focus of much of the early research concerned the amount of rest people need between practice trials to ensure an optimal learning environment. At issue was the question of whether *massed or distributed* practice trials provided for better learning of motor skills. Some researchers argued that distributed practice was better; others maintained that it did not make much difference which spacing strategy an instructor followed.

Although this early controversy focused on between-trial rest intervals, the study of practice distribution also concerns the amount of practice during each session of practice and the amount of rest between sessions. In this second practice distribution issue, the question of concern is whether it is better to have fewer but longer sessions or more but shorter sessions.

DEFINING MASSED AND DISTRIBUTED PRACTICE

Researchers use the terms **massed practice** and **distributed practice** in a general way to distinguish practice distribution schedules rather than assign specific amounts of time, which would allow for more objective definitions for these terms. The best way to understand these terms is to know that each involves an active practice, or work time; and each involves a rest period. The terms massed and distributed are typically defined in relation to each other. This means that the relative lengths of the time for active practice and rest are the essential aspects of establishing definitions for the two terms. As typically used, a massed practice schedule involves longer active practice, or work time, and shorter rest periods than a distributed schedule. Although rather vague, these definitions are necessary because of the types of situations to which they apply. In this discussion, we will consider massed and distributed practice in terms of schedules for both between and within practice sessions.

When applied to the *length and distribution of practice sessions,* a *massed schedule* will have fewer practice sessions than a distributed schedule, with each massed practice session requiring more trials and/or longer practice time. A *distributed schedule,* on the other hand, will distribute the same amount of practice time across more sessions, so that each session is shorter than each session in the massed schedule; the distributed practice sessions must be extended over a longer period to achieve the same total amount of practice trials.

massed practice a practice schedule in which the amount of rest between practice sessions or trials is very short.

distributed practice a practice schedule in which the amount of rest between practice sessions or trials is relatively long.

When these terms apply to the scheduling of practice within sessions, the focus is on the relative amount of time for active practice for a trial and the rest between trials. This means that a *massed schedule* will have either no rest or a very short rest interval between trials. A *distributed schedule* will have much longer rest intervals than a massed schedule.

THE LENGTH AND DISTRIBUTION OF PRACTICE SESSIONS

For most instruction and rehabilitation situations, the primary practice distribution concern is how to schedule within and between practice sessions for a specified amount of practice time. As we described earlier in this chapter, many instruction and rehabilitation situations have specified limits for the amount of available practice time. For example, in most clinical applications, a patient may receive treatment for only a limited number of sessions because of health care management restrictions. Also, in teaching and coaching situations, there is often little flexibility in the number of days available for classes or practice sessions. For example, if a teacher has only ten days for a unit of instruction, then the practice schedule must fit that limit. Similarly, if a dancer must perform in a concert that is one month away, then the rehearsal schedule must adjust accordingly. Thus, outside limitations may determine how many days a person should devote to practice. However, the instructor, coach, or therapist still decides the number of practice sessions and the length of each one.

The Benefit of More and Shorter Sessions

Research on the question of the length and distribution of practice sessions shows support for *the benefit of distributed practice.* This means that when experiments have compared a few long practice sessions with more frequent and shorter sessions, the results show that practicing skills during shorter sessions leads to better learning.

A classic example of research supporting this general conclusion is a study published many years ago by Baddely and Longman (1978). They were attempting to determine the best way to schedule training sessions for postal workers on a mail-sorting machine, which required operating a typewriter-like keyboard. The postal service had allotted a total of 60 hours and 5 days each week for training the workers. Although this available training time could be distributed in a variety of ways in terms of number of training sessions, the researchers distributed this amount of time in four different ways, which are described in table 17.1 in the Practice Schedule column. Two groups trained for one hour in each session. One of these two groups practiced for only one session each day, which resulted in a total training time of twelve weeks, whereas the second group had two sessions each day, thereby reducing the number of weeks in training to 6. Two other groups practiced for two hours in each session. One of these groups had only one session each day, whereas the other had two sessions per day. These latter two groups therefore had six weeks and three weeks of training, respectively. These four schedules illustrate the variety of ways the researchers distributed 60 hours of practice. The *most distributed schedule* required workers to train for twelve weeks, whereas the *most massed schedule* allowed them to complete their training in only three weeks.

TABLE 17.1 Results of the Baddeley and Longman Experiment with Practice Distribution Schedules for Training Postal Workers

Practice Schedule	Number of Hours to Type 80 Keystrokes/Minute
1 hr/session–1 session/day (12 weeks training)	55
1 hr/session–2 sessions/day (6 weeks training)	75
2 hrs/session–1 session/day (6 weeks training)	67
2 hrs/session–2 session/day (3 weeks training)	80+

Source: Data from Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency training session on the rate of learning to type. *Ergonomics, 21*, 627–635.

The primary difference between these schedules was in how long each session was and how many sessions occurred each day.

The results of this study are shown in table 17.1, which describes the number of hours the trainees required to achieve a typing speed of 80 keystrokes per minute, which was the motor performance goal for their training. Notice that only one of the four schedules (the most distributed schedule) resulted in the workers achieving this goal in the allotted training time of 60 hours (they did it in 55 hours). The other three groups required additional practice time. It is interesting that those in the most massed schedule group, which practiced two 2-hour sessions each day, never achieved this goal. After 80 hours of practice they were still doing only a little better than 70 keystrokes per minute.

Retention tests were given 1, 3, and 9 months after the workers had finished training. After 9 months, the most massed group performed worse on the typing speed test than the other groups, which performed about equally. Finally, the researchers obtained a very revealing result from the trainees' own ratings of the training schedules. Although most workers preferred their own schedule, those in the most massed group preferred theirs the most, whereas members of the most distributed liked theirs the least. Interestingly, these preferences were exactly opposite to the performance test results.

The results of this experiment indicate that fitting 60 hours of training into 3-week, where there had to be two 2-hour practice sessions each day, was a poor practice schedule. Although those in the most distributed schedule generally attained performance goals in the shortest time, they did not perform any better than two of the other groups on the retention tests. Given all the results, the authors concluded that the one-hour training sessions were more desirable than the two-hour sessions, and that one session per day was only slightly more effective than two sessions per day. However, having two 2-hour sessions each day was not a good training schedule.

More recent studies have shown similar learning benefits for distributed practice for a variety of motor skills, as the following examples demonstrate. Annett and Piech (1985) found that two 5 trial training sessions separated by one day led to better learning of a computer target-shooting game than one 10 trial session. One trial involved shooting at ten singly presented moving targets. On a retention test given one day after the end of the training session, the distributed group not only had more "hits" but also had less error in the shooting attempts.

Bouzid and Crawshaw (1987) reported similar results for the learning of word processing skills. Typists who practiced twelve skills during two sessions of 35 and 25 min each, separated by a 10 min break, required less time to learn the skills and had fewer errors on a test than typists who practiced the skills during one 60 min session.

Shea et al. (2000) showed that distributing practice sessions across days resulted in better learning than massing all the sessions within one day for a continuous dynamic balance task and a discrete key-press timing task. The results for the continuous balance task are shown in figure 17.2. Note that for the first session of trials (each trial involved 90 sec of continuous balancing), both the one-day practice (massed) and the two-day practice (distributed) groups performed similarly. However, during the second practice session the groups began to perform differently. By the end of this session, the distributed group, for whom this session was the next day, had significantly less balancing error. Importantly, this difference continued during the retention test, which each group performed one day after the end of the practice sessions.

Finally, in a study involving learning to putt in golf, Dail and Christina (2004) had novice golfers practice putting a 3.7 m distance for 240 trials. One group followed a massed practice schedule in which they performed all the trials on one day, with short breaks between blocks of 10 trials. In contrast, another group practiced according to a distributed schedule of 60 trials per day for four consecutive days. The results, which you can see in figure 17.3, showed that at the end of 240 practice trials, the distributed practice group performed at a higher level than the massed schedule group. More importantly, this difference continued one and seven days later on retention tests of

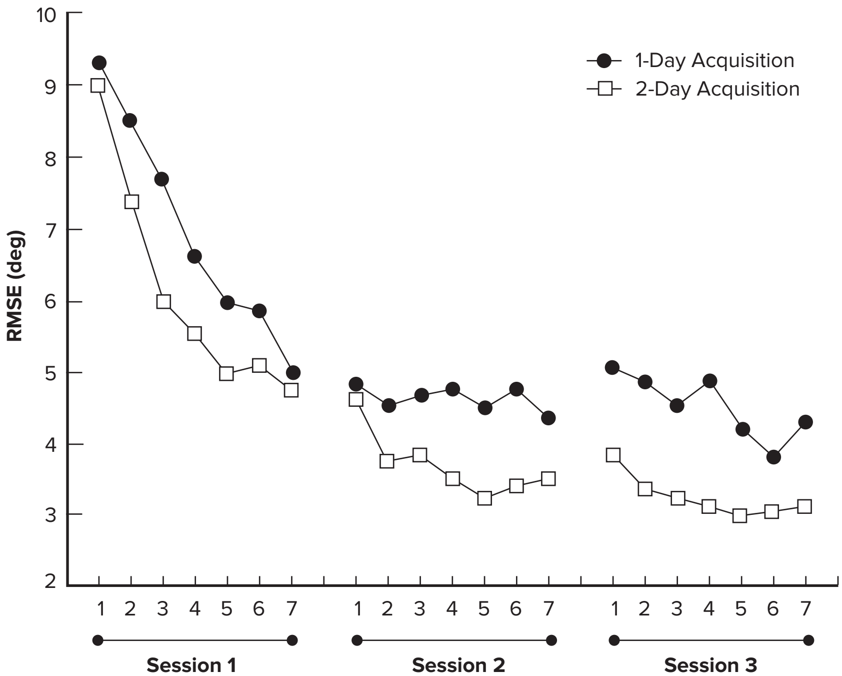

FIGURE 17.2 Results of the experiment by Shea et al. in which one group participated in two practice sessions on one day (circles) and another participated in one session on each of two days (squares). The graph shows the amount of balancing error (RMSE, which was calculated as the amount of deviation, in degrees, from horizontal) for each 90 sec trial on a dynamic balance task. *Source:* Figure 3, p. 745 in Shea, C. H., Lai, Q., Black, C., & Park, J. C. (2000). Spacing practice sessions across days benefit the learning of motor skills. *Human Movement Science, 19,* 737–760.

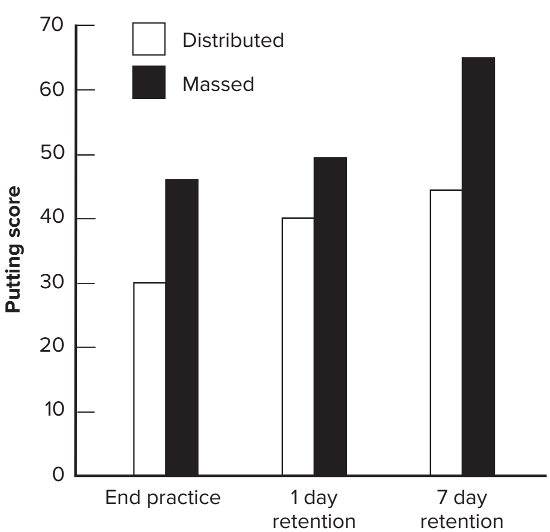

FIGURE 17.3 Results of the experiment by Dail and Christina in which two groups practiced putting a golf ball either in 240 trials in one day (massed practice) or in four days of 60 trials each (distributed practice). The graph shows the results (a lower score is better) at the end of the practice trials and during retention tests 1 and seven days later. *Source:* Data from Dail, T. K., & Christina, R. W. (2004). Distribution of practice and metacognition in learning and long-term retention. *Research Quarterly for Exercise and Sport, 75,* 148–155, figure 1.

60 trials. It is also interesting to note that at the end of each block of 10 trials during the practice sessions the experimenters asked the participants to predict their performance on the retention test. For this assessment of their own competence (i.e., metacognition), the participants who experienced the distributed schedule more accurately predicted their retention test performance.

Taken together, the results of these experiments support the learning advantage of distributed over massed practice schedules when the number and length of practice sessions is the concern. And when considered in terms of the types of motor skills involved in the experiments, the benefit of distributed practice extends to a variety of types of skills, which include discrete and continuous skills as well as open and closed skills. Finally, although the research does not give us a specific number and length of practice sessions that would be optimal for the learning of all motor skills, the conclusion that shorter and more practice sessions lead to better learning than longer and fewer sessions provides an excellent general principle on which to base specific decisions when planning practice, training, or rehabilitation sessions.

A CLOSER LOOK

Relating Practice Distribution and Contextual Interference to Skill Learning Contexts

The concept of contextual interference can be incorporated into practice distribution by organizing practice sessions to include principles related to both. The following are some examples that relate to three different skill learning contexts.

- **Physical education class.** If several drills or other kinds of activity are planned for the day's lesson, use a station-organization approach by assigning each skill or activity to a location in the gym or on the field so that there are several stations. Divide the class into groups and assign each to a station. Let the groups stay in their stations for about 12–15 minutes and then rotate to the next station. Continue this rotation approach for the entire period. If the class period is sufficiently long, allow for two or more rotations.
- **Sports-related practice.** Practices for team and individual sports typically include several activities. Rather than spend an extended amount of time on any one activity, divide in half the amount of time planned for each activity, and do each activity as two sets during practice. The two sets can be randomly or serially scheduled during the practice session.
- **Physical rehabilitation session.** Like sports-related practice sessions, rehab sessions typically involve several activities. If the planned activities allow, apply the approach described for sports-related practice by dividing in half the total amount of time planned for each activity, and do each activity as two randomly or serially scheduled sets during the session.

Explanations for the Distributed Practice Benefit

There are at least three possible reasons why the distribution of practice sessions across more days leads to better learning than massing the sessions within fewer days. One is that *fatigue* negatively influences learning for massed practice schedules. Although none of the experiments discussed in this section assessed participants' levels of fatigue, it is possible to suspect that fatigue influenced learning because of the task performance requirements. For example, in the Shea et al. (2000) experiment, participants performed a continuous dynamic balance task for 90 sec on each trial. The massed practice schedule required them to perform 14 trials on the same day with only a 20 min break between trials 7 and 8. On the other hand, participants in the distributed practice schedule performed the second set of seven trials on the following day. Similarly in the Dail and Christina (2004) experiment, participants who experienced the massed practice schedule performed 240 putts in one session, with short rest breaks only after each set of 10 trials. In contrast, those who practiced according to the distributed schedule performed only 60 trials in each session.

Second, the massing of practice within a day or a few days may reduce the amount of *cognitive effort* used on each trial as practice continues beyond a certain critical amount. We considered this explanation earlier in this chapter when we discussed reasons why more practice beyond a certain amount could lead to diminished learning. The massing of practice trials may institute a practice condition in which performance of the skill on each trial becomes so repetitious that it becomes monotonous or boring. As a result, the learner begins to decrease the amount of cognitive effort involved in each trial, which in turn diminishes the level of learning.

The possibility that either or both fatigue and reduced cognitive effort accounted for the poorer learning that resulted from the massed compared to the distributed practice sessions can be seen in the results of the Shea et al. (2000) and Dail and Christina (2004) experiments. As you can see in figure 17.2, lower practice performance in the Shea et al. study did not begin until the last several trials for the massed practice condition. This suggests that as participants continued to practice, the effects of fatigue and/or reduced

LAB LINKS

Lab 17 in the Online Learning Center Lab Manual provides an opportunity for you to experience a comparison of the effects of massed and distributed practice on the learning of a discrete motor skill.

cognitive effort eventually began to influence their performance in a negative way. And this influence affected not only their practice performance but also their retention test performance, indicating an influence on their learning the skills.

The third explanation relates to *memory consolidation,* which is a long-term memory storage process. The memory consolidation hypothesis proposes that to store in memory the relevant information we need to learn a skill, certain neurobiochemical processes must occur. These processes, which transform a relatively unstable memory representation into a relatively permanent one, require a certain amount of time without additional practice of the same skill. The distribution of practice across several days provides a better opportunity for the memory consolidation process to take place than does the massing of practice within a day or a few days (see Brashers-Krug, Shadmehr, & Bizzi, 1996; Shadmehr & Brashers-Krug, 1997; Simmons, 2011). In addition, sleep appears to make an important contribution to the consolidation process (e.g., Boutin et al., 2018; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002).

THE INTERTRIAL INTERVAL AND PRACTICE DISTRIBUTION

By far the greatest amount of research on the distribution of practice has investigated the length of the intertrial interval, which relates to the amount of rest a person has between practice trials. One of the problems confronted when trying to understand this research relates to the definition problem described earlier in this chapter.

To elaborate on the general definitions presented earlier, we shall define *massed practice* as practice in which the amount of rest between trials is either very short or nonexistent, so that practice is relatively continuous. *Distributed practice* is practice in which the amount of rest between trials or groups of trials is relatively long. Although the terms "very short" and "relatively long" in these definitions are somewhat ambiguous, they allow us to generalize as much as possible from the research literature on massed versus distributed practice to motor skill learning situations.

A History of Controversy

Although a great deal of research literature exists concerning the distribution of practice as it relates to the length of the intertrial interval, it is filled with

To enhance the learning of continuous motor skills, such as jumping rope, practice sessions should follow distributed schedules.

Ryan McVay/Getty Images

controversy about which schedule leads to better learning. The controversy is evident in reviews of this literature as well as motor learning textbooks; both provide a variety of answers to the practice distribution question.

Two problems underlie the controversy surrounding this issue. The first relates to the issue of practice performance versus learning effects. Many of the experiments on massed versus distributed practice did not include retention or transfer trials. The second problem is that researchers generally have failed to consider that the two practice distribution schedules may have different learning effects on different types of skills.

Two reviews of the distributed practice research literature have helped resolve these problems and the controversy about which practice schedule is better for learning motor skills (Donovan & Radosevich, 1999; Lee & Genovese, 1988). Both reviews involved a statistical analysis, known as meta-analysis, to evaluate the research literature. Their conclusion was that the *type of task* was an important variable in determining practice distribution effects for schedules related to the length of intertrial rest intervals. More specifically, Lee and Genovese (1988, 1989) provided evidence that the type of practice distribution schedule that results in better learning depends on whether the skill is continuous or discrete. We will look at each of these types of skills next.

Continuous skills. Continuous skills have been the most common type of motor skills used to investigate the effects of massed versus distributed practice between trials. And the most popular task has been the rotary pursuit task, in which a person must keep a handheld stylus in contact with a small disk on a rotating turntable for as long as possible. A trial is usually a specified length of time, such as 20 or 30 sec. What makes this type of task useful for investigating the issue of massed versus distributed practice is that it is quite easy to specify massed and distributed intertrial interval lengths. Massed practice schedules typically have few, if any, seconds of rest between trials, whereas the intervals in distributed schedules are as long as or longer than the trials themselves. Because of this, researchers can establish intertrial interval lengths that are readily identifiable as distinctly massed or distributed. The Lee and Genovese (1988) review found that the consistent result has been that *distributed schedules lead to better learning* than massed schedules for learning continuous motor skills.

Discrete skills. When researchers use discrete skills to investigate the issue of intertrial massed versus distributed practice, a problem arises that is directly related to the definition problem we discussed earlier. If a massed schedule allows no rest between trials, whereas a distributed schedule involves a rest interval that is the same length as the practice trial, then the two contrasted intertrial intervals will be essentially the same length, because a discrete response is typically very short. For example, if people are practicing a rapid-aiming task that has a duration of approximately 150 msec, the distributed practice condition could, by definition, have a 150 msec intertrial interval. But if the massed condition had no rest between trials, only 150 msec would separate the two practice schedules. Thus, the operational definition of the terms "massed" and "distributed" becomes especially important in experiments using discrete tasks. Probably one reason this has not troubled researchers is that discrete tasks seldom have been used for comparing massed to distributed practice. In fact, in their comprehensive review, Lee and Genovese (1988) found only one study in the research literature that used a discrete task (Carron, 1969). The results of that study, and one subsequently reported by Lee and Genovese (1989), provided evidence that *massed practice schedules result in better learning* for discrete motor skills. Further support for this view was more recently provided in a study by Panchuk and colleagues (Panchuk, Spittle, Johnston, & Spittle, 2013) for learning a handball pass in Australian rules football. The skill is a discrete skill requiring a punch by one hand of a football held by the other hand as a way to pass the ball to a teammate. Their results showed massed practice of

1 sec. between trials led to better learning (as assessed by 10-min. and 2-week retention tests) than distributed practice of 30 sec. between trials.

A Final Comment about Practice Distribution and Motor Learning

In this discussion of practice distribution effects on the learning of motor skills, an important distinction was made between two specific issues related to practice distribution: the length and frequency of practice sessions, and the length of the intertrial interval for a series of practice trials. These two issues are often overlooked as distinct even though research evidence supports the distinction. A significant reason for the distinction is that two different conclusions concerning how to best distribute practice are associated with each issue. When the length and frequency of practice sessions is the practice distribution concern, distributed practice results in better learning than massed practice, regardless of the type of skill being learned. On the other hand, when the length of the intertrial interval for a series of practice trials is the concern, the type of skill being learned is an important consideration.

SUMMARY

Issues concerning the *amount of practice* needed to achieve specific skill performance goals historically have been discussed and investigated within the topic of *overlearning.*

- Overlearning is the continuation of practice beyond the amount needed to achieve a certain performance criterion.
- Research investigation of overlearning as a practice strategy has shown that the view that "more is better" is not always appropriate for the learning of motor skills, especially in terms of the benefits derived in relation to the amount of practice experienced; that is, there appears to be a *point of diminishing returns* for amount of practice.
- Research has shown that learning deficits can result when too much overlearning is involved in learning of motor skills that are simple and easy to learn; this effect is probably due to a decrease in the amount of cognitive effort applied after a certain amount of practice.

Issues related to the *distribution of available practice time* involve massed and distributed practice schedules. The terms *massed* and *distributed* are generally defined in relation to each other according to the practice schedule characteristics of each.

- One type of practice distribution schedule involves the *length and frequency of practice sessions;* this type typically concerns a massed schedule of longer sessions within a day or a few days compared to a distributed schedule of shorter sessions across more days than the massed schedule.
- Research evidence shows that practice sessions can be too long and too infrequent to lead to optimal learning. Typically, better learning results when people practice skills in larger numbers of shorter practice sessions than when they do so in sessions that are long and fewer in number.
- We discussed three hypotheses proposed to explain why distributed practice sessions lead to better learning than massed sessions: a fatigue hypothesis, a cognitive effort hypothesis, and a memory consolidation hypothesis.
- The second type of practice distribution schedule involves the *length of the intertrial interval,* which is the rest period between practice trials.
- Research evidence shows that the optimum length for the intertrial interval depends on whether the skill is continuous or discrete. For continuous skills, distributed practice schedules are typically better for learning, but massed practice schedules are preferable for discrete skills.

POINTS FOR THE PRACTITIONER

Overlearning:

- The overlearning strategy works best when the practitioner knows how much practice (i.e., number of trials or amount of time) a person needs to achieve a certain performance level.

- The overlearning strategy can be effective for skills that people will practice for a specified amount of time but then not perform for some period of time afterward (e.g., the disassembling and assembling of the machine gun in the Schendel and Hagman study).
- Practitioners should not base the amount of extra practice to provide on the view that "more is better." There can be a point of diminishing returns where the extra practice does not yield results proportional to the amount of time and effort required by the extra practice, and the extra practice could actually lead to poorer test performance than would no extra practice. One way to determine the amount of extra practice is to require 100 percent more practice than the amount required by the person to achieve the specified performance criterion.
- Practice requiring the performance of variations of skill characteristics can be an effective means of establishing an overlearning situation.

Practice Distribution:

- Practice sessions can be too long. When in doubt about how long a session should be, opt for a shorter rather than a longer amount of time. If people need more practice time, add more sessions rather than lengthen sessions.
- More frequent practice sessions are preferable to fewer sessions.
- Time saved in terms of the number of days of practice can be a false savings because massing sessions too close together can lead to poor long-term results.
- The length and number of sessions desired by students, trainees, athletes, or patients may not represent the best schedule for learning the skills they need to learn. Remember that if the postal trainees in the Baddeley and Longman study had been allowed to choose their own training schedules, they would have chosen the schedule that led to the poorest learning.
- Make practice trials relatively short for skills that last a reasonably long time and require repetitive movements, such as swimming, bicycling, dancing, keyboarding, and piano playing. Shorter but more trials lead to better learning than longer trials that are infrequently repeated.
- For skills that require relatively brief amounts of time to perform (e.g., hitting a golf ball, serving a tennis ball, shooting a basketball, throwing darts, reach-and-grasp activities), make rest intervals between practice trials short.

RELATED READINGS

Ammons, R. B. (1988). Distribution of practice in motor skill acquisition: A few questions and comments. *Research Quarterly for Exercise and Sport, 59,* 288–290.

Batson, G., & Schwartz, R. E. (2007). Revisiting the value of somatic education in dance training through an inquiry into practice schedules. *Journal of Dance Education, 7*(2), 47–56.

Cecilio-Fernandes, D., Cnossen, F., Jaarsma, D. A. D. C., & Tio, R. A. (2017). Avoiding surgical skill decay: A systematic review on the spacing of training sessions. *Journal of Surgical Education, 75,* 471–480.

Clark-Williams, J., Giles, G. M., & Baxter, D. M. (2014). Revisiting the neurofuncitonal approach: Conceptualizing the core components for the rehabilitation of everyday living skills. *Brain Injury, 28,* 1646–1656

Croce, R. V., & Jacobson, W. H. (1986). The application of two-point touch cane technique to theories of motor control and learning: Implications for orientation and mobility training. *Journal of Visual Impairment and Blindness, 80,* 790–793.

Franceschini, G., Terzini, M., & Zanetti, E. (2017). Learning curves of elite car racers. *International Journal of Sports Science & Coaching, 12,* 245–251.

Garcia, J. A., Moreno, F. J., Reina, R., Menayo, R., & Fuentes, J. P. (2008). Analysis of effects of distribution of practice in learning and retention of a continuous and a discrete skill presented on a computer. *Perceptual and Motor Skills, 107,* 261–272.

Gerbier, E., & Topping, T. C. (2015). The effect of distributed practice: Neuroscience, cognition, and education. *Trends in Neuroscience and Education, 4,* 49–59.

Krishnan, C. (2019). Learning and interlimb transfer of new gait patterns are facilitated by distributed practice across days. *Gait & Posture, 70,* 84–89.

Lee, T. D., & Wishart, L. R. (2005). Motor learning conundrums (and possible solutions). *Quest, 57,* 67–78.

Mackay, S., Morgan, P., Datta, V., Chang, A., & Darzi, A. (2002). Practice distribution in procedural skills training—A randomized controlled trial. *Surgical Endoscopy and Other Interventional Techniques, 16,* 957–961.

Mitchell, E. L., Lee, D.Y., Sevdalis, N., Partsafas, A. W., Landry, G. J., Liem, T. K., & Moneta, G. L. (2011). Evaluation of distributed practice schedules on retention of a newly acquired surgical skill: A randomized trial. *The American Journal of Surgery, 201,* 31–39.

Peiris, C. L., Taylor, N. F., & Shields, N. (2011). Extra physical therapy reduces patient length of stay and quality of life with acute or subacute conditions: A systematic review. *Archives of Physical Medicine and Rehabilitation, 92,* 1490–1500.

Rhodenizer, L., Bowers, C. A., & Bergondy, M. (1998). Team practice schedules: What do we know? *Perceptual and Motor Skills, 87,* 31–34.

Sanli, E. A., & Carnahan, H. (2018). Long-term retention of skills in multi-day training contexts: A review of the literature. *International Journal of Industrial Ergonomics, 66,* 10–17.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3,* 207–217.

Siengsukon, C. F., & Boyd, L. A. (2009). Does sleep promote motor learning? Implications for physical rehabilitation. *Physical Therapy, 89,* 370–383.

Todd, M., & Barrow, C. (2008). Teaching memory-impaired people to touch type: The acquisition of a useful complex perceptual-motor skill. *Neuropsychological Rehabilitation, 18,* 486–506.

Verhoeven, F. M., & Newell, K. M. (2018). Unifying practice schedules in the timescales of motor learning and performance. *Human Movement Science, 59,* 153–169.

STUDY QUESTIONS

1. Discuss two different ways the term *overlearning* can be used to relate to learning motor skills.

2. (a) Define the term *procedural skill* as it is commonly used in the motor learning literature. (b) What was the recommendation from the results of the Schendel and Hagman study for using an overlearning strategy to help people learn a procedural skill? Indicate why they made this recommendation.

3. Discuss the evidence that would support the view that “more is better” may not be the best approach to implementing an overlearning strategy to help people learn a motor skill.

4. Describe how the concept of practice distribution is related to the intertrial interval and to the length and distribution of practice sessions. Describe a motor skill learning situation for each.

5. Describe three research studies that provide evidence that demonstrates the benefit of distributed over massed practice sessions for learning a motor skill.

6. Discuss three possible explanations for the learning benefit that results from distributed practice sessions compared to massed schedules for the length and number of practice sessions scheduled for learning a motor skill.

7. (a) How do massed and distributed intertrial interval schedules differentially influence the learning of discrete and continuous motor skills? (b) Why do you think there is a difference in how massed and distributed intertrial interval schedules influence the learning of discrete and continuous skills?

8. Describe how you would implement your knowledge about massed and distributed practice in *one* of the following situations: a physical education or dance class; a practice session for a sport; a physical or occupational therapy session.

Specific Application Problem:
Describe a situation in which you are working with people to help them improve their performance of a motor skill. Part of your job is to determine the amount of time the people need to receive your assistance, and then to schedule the length and number of sessions for them to practice the skill with your assistance. Present a plan that would describe how you would respond to both of these scheduling issues. Include in your plan a rationale to justify these decisions.