CHAPTER 18

Whole and Part Practice

Concept: Base decisions about practicing skills as wholes or in parts on the complexity and organization characteristics of the skills.

After completing this chapter, you will be able to

- Define the terms *complexity* and *organization* as they relate to the relationships among the parts or components of a complex motor skill
- Describe ways to apply the part-practice methods of *fractionization* and *segmentation* to the practice of motor skills
- Describe several ways to apply *simplification* methods to the practice of motor skills

APPLICATION

An important decision you must make when you teach any motor skill concerns whether it is better to have the learner practice the skill in its entirety or by parts. Consider the following sport skill instruction situation as an example. Suppose you are teaching a beginning tennis class. You are preparing to teach the serve. Most tennis instruction books break down the serve into six or seven parts: the grip, stance, backswing, ball toss, forward swing, ball contact, and follow-through. You must decide whether to have the students practice all of these parts together as a whole or to have them practice each component or group of components separately.

The question of whether to use whole or part practice also confronts professionals in a rehabilitation setting. For example, when a patient needs to learn the task of getting out of bed and getting into a wheelchair, this decision comes into play. Although this task has distinct and identifiable parts, the therapist must determine whether to have the patient practice each part separately or always practice the whole sequence.

There are other situations in which the whole–part practice decision must be made. For example, a person may need to learn to perform a skill that requires the asymmetric use of both hands, which is common for playing many musical instruments, such as the piano, guitar, or drums, or performing many activities of daily living, such as opening or closing the lid of a jar. Other skills involve the use of either hand, or foot, but only one at a time, such as dribbling a basketball and kicking a soccer ball. In these skills, proficiency with either hand or foot is important for highly skilled performance.

In all the skill learning situations, the practitioner will need to decide whether to begin practice sessions with instruction that engages people in practicing the whole skill or parts of the skill. And if the latter option is chosen, a decision must be made about what kind of part practice. In the following discussion, we will consider these issues in a way that should provide a basis for making these decisions.

Application Problem to Solve Think about the various motor skills that you perform daily or for recreational purposes. If you had to teach each of these skills to someone, how would you decide whether it would be best for that person to begin learning each skill by practicing the whole skill or parts of the skill?

DISCUSSION

The issue of whether to use whole or part practice has been a topic of discussion in the motor learning literature since the early 1900s. Unfortunately, that early research often led to more confusion than understanding. One of the reasons was that researchers tended to investigate the issue in terms of whether one or the other type of practice is better for learning specific skills, without concern for determining skill-related characteristics that could help them make useful generalizations about which practice scheme would be preferable for certain skills. For example, the question of whole versus part practice was investigated for learning a maze task (Barton, 1921) or a piano score (Brown, 1928) as well as for learning how to juggle (Knapp & Dixon, 1952) and master gymnastic skills (Wickstrom, 1958), to name a few examples. Although this research provided useful information about teaching these specific skills, it did little to establish a guiding principle for decisions about whether to use whole or part practice.

An important part of teaching balance beam skills and routines is the decision to practice them as a whole skill or routine, or in parts.

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SKILL COMPLEXITY AND ORGANIZATION

A breakthrough in a guiding principle for the use of whole versus part practice occurred in the early 1960s, when James Naylor and George Briggs (1963) hypothesized that the *organization and complexity characteristics of a skill could provide the basis for a decision to use either whole or part practice.* This hypothesis made it possible for practitioners to determine for any skill which of these two methods of practice would be preferable.

Naylor and Briggs defined **complexity** in a way that is consistent with the term's use in this text. They stated that *complexity* refers to the number of parts or components in a skill, as well as the attention demands of the task. This means that *a highly complex skill would have many components and demand much attention,* especially from a beginner. Performing a dance routine, serving a tennis ball, and getting out of bed and into a wheelchair are examples of highly complex skills. Low-complexity skills have few component parts and demand relatively limited attention. For example, the skills of shooting an arrow and picking up a cup are low in complexity. *It is important to keep the term complexity distinct from difficulty.* As you saw in the discussion of Fitts' law in chapter 7, skills of the same complexity can vary in their level of difficulty.

The **organization** of a skill refers to the relationships among the component parts of a skill. A skill has a *high level of organization* when its component parts are spatially and temporally interdependent. This means that the successive parts of a highly organized skill are like a chain of events in which the spatial-temporal performance characteristics of any one part are dependent on the spatial-temporal performance characteristics of the part performed just before it. Because of this characteristic, it would be difficult to perform only one part of a highly organized skill. The jump shot in basketball is a good example of a highly organized skill, because how a person performs each part will depend on the manner in which he or she performed the part(s) that preceded it. Although the arm and hand movements involved in the release of the ball could be practiced separately, the spatial location of the arm and hands as well as the timing of the ball release must be related to other parts of the skill, such as the direction and the height of the jump. In contrast, a skill has a *low level of organization* when the spatial-temporal relationships among the component parts of a skill are relatively independent. As a result, it is possible to practice any one component part by itself, because its spatial-temporal performance characteristics do not depend on those of the part that precedes it. Examples here include many gymnastics floor routines, buttoning a shirt, and handwriting certain words.

Skill Characteristics and the Decision to Use Whole or Part Practice

Based on the Naylor and Briggs hypothesis, assessing the levels of complexity and organization of a skill helps the practitioner decide whether to use whole or part practice. If the skill is *low in complexity and high in organization,* practice of the whole skill is the better choice. This means that people learn relatively simple skills in which the few component parts are highly related most efficiently using the whole-practice method. For example, the skills of buttoning a button, throwing a dart, and putting a golf ball have the characteristic of low complexity and high organization. On the other hand, people learn skills that are *high in complexity and low in organization* most efficiently by the part method. For example, the skills of executing a tumbling routine in gymnastics; reaching for, grasping, and drinking from a cup; and changing a flat tire on a car have the high complexity and low organization characteristic.

To determine which complexity and organization combinations describe a particular skill, it is necessary to first analyze the skill. This analysis needs to focus on identifying the skill's component parts and the extent to which the spatial-temporal performance characteristics of those parts are interdependent. On the basis of this analysis you can then decide which levels of skill complexity and organization best represents the skill.

By far, most of the motor skills we perform as a part of our daily living activities and sports would be characterized as more complex than simple. This means that for most skills, the practitioner must determine the level of organization that characterizes the skill. For skills that we would place somewhere between the extremes of low and high on the organization continuum, an additional task analysis step is required. Then, it is necessary to determine which component parts are independent of the others and which group together as interdependent. The result of this analysis will determine which parts could be practiced independently. That is, some of the "parts" a person practices would consist of more than one of the component parts that resulted from the initial task analysis. This grouping of parts can be thought of as a "natural unit" within the skill. Because teachers, coaches, and therapists typically work with motor skills that would suggest some sort of part practice, we will first consider issues relevant to part practice.

complexity the number of parts or components and the degree of information processing that characterize a skill; more complex skills have more component parts and greater information-processing demands than less-complex skills.

organization when applied to a complex motor skill, the relationships among the components of the skill.

A CLOSER LOOK

An Example of Making the Decision Regarding Use of Whole or Part Practice

Use skill analysis to determine whether to practice juggling three balls as a whole or in parts:

Skill Analysis

Complexity characteristics

1. Hold the three balls in two hands.
2. Toss ball 1 from hand 1.
3. Catch ball 1 in hand 2 while tossing ball 2 with hand 2.
4. Catch ball 2 in hand 1 while tossing ball 3 with hand 2.
5. Catch ball 3 in hand 1 while tossing ball 1 with hand 2.
6. Repeat steps 2 and 5.
7. Between-component timing: critical for performance.

Organization characteristics. Doing any one part without doing the part that precedes or follows it does not allow the learner to experience critical between-component timing aspects.

Conclusion. Three-ball juggling involves several component parts that are highly interdependent. Therefore, juggling three balls is relatively high in complexity and in organization. *Practicing the whole skill* is the predicted appropriate method.

Empirical Evidence Supporting the Whole-Practice Prediction

In an experiment that has become a classic, Knapp and Dixon (1952) told university students who had no previous juggling experience to practice until they could make 100 consecutive catches while juggling three paddle-tennis balls. Results showed that students who followed a whole-practice approach achieved this goal in sixty-five trials, whereas those who followed a part-practice regime needed seventy-seven trials. Because juggling is relatively high in complexity, an important caveat is that whole practice might not be the most effective practice strategy for learners whose information processing capacity is limited. In support of this idea, Chan, Luo, Yan, Cai, and Peng (2015) showed that children's age determined whether whole or part practice was most effective for learning a juggling task. Fifth graders learned best with whole practice, whereas first and third graders learned best with part practice.

Continuous, discrete, and serial skills. Some researchers have used the skill classification system in which skills are classified as continuous, discrete, or serial, which we discussed in chapter 1, as a way to consider the complexity and organization characteristics of a motor skill. Continuous and serial skills would be generally high in complexity but would differ in their levels of organization, although most would have a high level of organization because of the spatial-temporal relationships among the parts of these skills. Discrete skills are low in complexity because they consist of one identifiable part, which would put them at the high end of the organization continuum. Researchers who have investigated the whole–part practice issue on the basis of these skill classification categories have reported results that are generally consistent with the predictions described in the previous section for the relationship between the complexity-organization characteristics of a skill and whether the skill should be practiced as a whole or in parts (for a review of this research, see Lee, Chamberlin, & Hodges, 2001).

PRACTICING PARTS OF A SKILL

The decision to use a part-practice strategy unfortunately solves only part of the problem, because there are several different ways to implement a part-practice approach to the practice of a skill. When selecting a part-practice strategy, it is important to apply transfer of learning principles, which we discussed in chapter 13. Part-practice strategies should involve positive transfer between and among the practiced parts of a task and between the practiced parts and the whole task.

In their important review of the research literature related to skill training methods, Wightman and Lintern (1985) classified three commonly used part-task strategies. One, called **fractionization,** involves practicing individual limbs first for a skill that involves the asymmetric and simultaneous coordination of the arms or legs. A second method, called **segmentation,** involves separating the skill into parts and then practicing the parts so that after the learner practices one part, he or she then practices that part together with the next part, and so on. Researchers also have called this method the *progressive part method* and the chaining method. A third method of part practice is called **simplification.** This method is actually a variation of a whole-practice strategy but involves reducing the difficulty of the whole skill or of different parts of the skill.

Fractionization: Practicing Asymmetric Limb Coordination Skills

Many of the motor skills discussed throughout this text require people to simultaneously move their arms or legs to achieve a specific spatial and/or temporal goal. Recall from the discussion of coordination in chapter 5 that the coordination tendency is for the arms or legs to move spatially and temporally together. What this means in terms of part versus whole practice is that because of this coordination tendency, a skill that requires symmetric spatial-temporal coordination of the arms (e.g., the butterfly and breaststroke in swimming) or legs (e.g., the flutter kick for a crawl stroke in swimming or the leg movements for cross-country skiing) would be high in organization. As a result, a whole-practice approach would be preferable. However, when the task requires the two arms or legs simultaneously to do *different* spatial and/or temporal movements (i.e., asymmetric coordination), the question of the use of a part-practice strategy becomes more of an issue.

Because asymmetric coordination of the arms is more characteristic of motor skills than asymmetric coordination of the legs, we will address skills in this section that we referred to in chapter 7 as asymmetric bimanual coordination skills. Consider, for example, the simultaneous arm movements involved in the playing of many musical instruments, such as the guitar, violin, and accordion. Each requires the person to simultaneously produce distinctly different movement patterns with each arm and hand. Other instruments, such as the piano and drums, may require this type of movement characteristic but also include simultaneous asymmetric movement of the legs. Sport skills such as the sidestroke in swimming and the tennis serve also involve this type of bimanual coordination. Is a part-practice strategy the best approach for learning these types of skills, or would a whole-practice approach be preferable? Some controversy exists among researchers, and there is evidence to support either approach (see Walter & Swinnen, 1994). If a part-practice approach is used, the most appropriate strategy is *fractionization.*

For asymmetric bimanual skills, the fractionization strategy involves practicing each arm or hand individually before performing the skill bi-manually. A relevant question related to the use of this strategy is this: Does it matter which arm or hand practices first? A feature of asymmetric bimanual coordination skills that is important to consider in answering this question is that one arm or hand will sometimes perform a movement, or sequence of movements,

fractionization a part-task training method related to asymmetric coordination skills that involves practicing each arm or leg separately before performing with them together.

segmentation a part-task training method that involves separating the skill into parts and then practicing the parts so that after one part is practiced, it is then practiced together with the next part, and so on; also known as the *progressive part method.*

simplification a part-task training method that involves reducing the difficulty of specific parts or features of a skill.

A CLOSER LOOK

The Whole–Part Practice Decision for an Orthopedic Surgical Task

The training of surgeons involves teaching surgical tasks that require practice. Because these tasks vary in their complexity and organization characteristics, decisions concerning the use of whole- or part-practice procedures are essential to teaching surgeons to acquire the skills needed to perform these tasks. Researchers in Toronto, Canada (Dumbrowski, Backstein, Abughaduma, Leidl, & Carnahan, 2005), used this point of view to investigate the procedures used to train medical students to perform the surgical task of bone plating, which involves the immobilizing of a fractured bone by attaching a metal plate to it. The researchers addressed two questions: (1) Is it better to initially practice the bone-plating procedure by performing the whole procedure on each practice attempt or by practicing the individual skills that constitute the procedure? (2) If the answer to the first question is that a part-practice strategy is preferable, then would a blocked or random practice schedule for the individual parts be better for learning?

The bone-plating surgical task: A task analysis by two orthopedic surgeons showed that the task is a serial task in which the parts are distinct, must be performed in a specific order, and are interrelated because each succeeding part depends on the performance of the preceding parts. The task analysis identified five parts: (1) sizing the plate and clamping it to the bone, (2) drilling six holes of precise depth and dimension in the bone, (3) measuring the depth of each drilled hole, (4) creating threading in the bone for the screws (called "bone tapping"), and (5) inserting the screws.

Participants and practice procedures: Twenty-eight first- and second-year medical students who had no experience in the bone-plating procedure practiced the task on artificial ulna bones. They first watched a video of a surgeon performing the entire procedure and then performed one pretest trial of the entire procedure before they began a 60 min practice period.

Whole- and part-practice conditions: The students were assigned to one of three groups, one for each of the practice conditions: (1) *whole practice*—performed all five parts in sequence on each practice trial; (2) *blocked part practice*—practiced one part of the procedure three times in a 12 min session before practicing the next part; (3) *random part practice*—practiced each part of the procedure in random order in three 20 min sessions. Each student practiced each part three times during the practice session and received augmented feedback as needed from an orthopedic surgeon.

Posttests: The students performed the entire procedure one time immediately after the end of the 60 min practice session and then one more time 30 min later. They received no augmented feedback during the posttests.

Results: Of the several performance measures, a checklist of specific procedures and a final product evaluation (both were determined and evaluated by a panel of three skilled orthopedic surgeons) showed that whole practice led to the most improvement and best final product. Random part practice was next, although not statistically significantly different from whole practice, and blocked practice was third on both performance measures.

Recommendations for bone-plating surgery training: A whole-practice strategy is recommended for the training of the bone-plating surgical procedure. However, if a part-practice strategy is used, the parts should be practiced in a random order, which could be done by having a station for each part and having students randomly rotate through the stations after performing one trial at each station.

that is more difficult or complex than the other. parts. Research evidence (e.g., Sherwood, 1994) suggests that practice should begin with the hand or arm that must perform the more difficult or complex movement.

An interesting exception to strict use of practicing each limb separately before performing the skill bimanually was an experiment by Kurtz and Lee (2003) in which participants learned an asymmetric bimanual polyrhythm task. The task simulates

A CLOSER LOOK

Whole- and Part-Practice Conditions that Facilitate the Learning of Bimanual Coordination Skills

Bimanual coordination skills that require each arm to simultaneously perform different movements are difficult to learn because of the tendency for the two arms to spatially and temporally move together. Walter and Swinnen (1994) discussed various training approaches that would facilitate learning to break this "habit" for skills that require different simultaneous arm movements. Their research involved a task that required participants to place each forearm on a lever on a tabletop and to move them simultaneously so that one arm made a one-direction elbow-flexion movement and the other made a two-direction elbow-flexion-extension movement in a criterion amount of time. Their research demonstrated that the following three techniques accomplished this learning goal. Note that one involved part-task practice and two involved whole-task practice.

- **Fractionization.** The movement patterns were practiced separately for each arm and then with the two arms moving simultaneously.
- **Speed-based simplification.** Initial practice of the bimanual task was at a slower speed than the criterion; subsequent sets of trials involved the progressive increase of the speed until the criterion speed was practiced.
- **Augmented feedback.** Practice involved the two arms simultaneously moving and augmented feedback provided after each trial as KP (the acceleration-time traces for each limb) or KR (correlation values indicating the degree of between-arm relationship).

a situation that occurs in the playing of musical instruments when one hand plays one rhythmic pattern while the other plays a different pattern, which is not uncommon for playing the piano or drums. Participants practiced a 2:3 polyrhythm for time cycles of 1.8 sec (i.e., 1,800 msec). To perform the polyrhythm correctly, the left hand taps two beats of equal time intervals (i.e., one every 900 msec) while the right hand tapped three beats of equal intervals (i.e., one every 600 msec). This means that the right hand made one tap 600 msec after the beginning of a cycle, then the left hand made one tap 300 msec later (i.e., 900 msec from the beginning), 300 msec later the right hand made its second tap, and 600 msec later, both hands made their final tap simultaneously.

Practice involved tapping according to a metronome sound. A part-practice group practiced each hand separately; a whole-practice group practiced both hands together every trial, and a part–whole practice group practiced each hand separately while listening to a metronome beat for both hands. Thus, unlike any of the experiments discussed earlier, in which participants practiced an asymmetric bimanual skill, the Kurtz and Lee experiment included a practice condition that involved unimanual part practice but with participants listening to the same rhythmic pattern which the whole-practice group practiced. Results, which can be seen in figure 18.1, showed that whole and part–whole practice conditions led to the best transfer performance of the bimanual polyrhythm, which was without a metronome. Although these results differ from those of the typical fractionization type of practice, the discrete polyrhythmic characteristic of the skill may account for the difference. However, it is important to note that consistent with the fractionization practice strategy, the part–whole practice strategy used in the Kurtz and Lee experiment involved unimanual practice. The unique characteristic was that their unimanual practice included simultaneously hearing the rhythmic pattern of the bimanual task.

Segmentation: The Progressive Part Method

Although practicing individual parts can be helpful in learning a skill, the learner can experience difficulty later, when he or she has to put the parts back together with the whole skill. One way to overcome this problem is to use the *progressive*

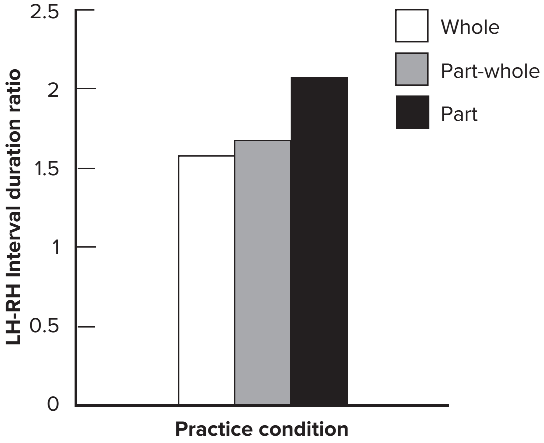

FIGURE 18.1 Results of the experiment by Kurtz and Lee in which three groups practiced a bimanual polyrhythm of two beats for the left hand (LH) and three beats for the right hand (RH) within a 1.8 sec interval. The LH-RH Interval Duration Ratio is the average performance of the left hand as a ratio relative to the right hand. A perfect polyrhythm performance is a 1.5 ratio. The graph shows the bimanual polyrhythm performance on the transfer test for groups that engaged in part-, part- and whole-, and whole-task practice prior to the transfer test. *Source:* Data from Kurtz, S., & Lee, T. D. (2003). Part and whole perceptual-motor practice of a polyrhythm. *Neuroscience Letters, 338,* 205–208, figure 3.

part method. Rather than practicing all parts separately before putting them together as a whole skill, the learner practices the first part as an independent unit, then practices the second part—first separately, and then together with the first part. In this way, each independent part progressively joins a larger part. As practice continues, the learner eventually practices the entire skill as a whole.

A common example of the progressive part method is a frequently used practice scheme for learning the breaststroke in swimming. The breaststroke is easily subdivided into two relatively independent parts, the leg kick and the arm action. Because a difficult aspect of learning the breaststroke is the timing of the coordination of these two parts, it is helpful for the learner to reduce the attention demands of the whole skill by practicing each part independently first. This enables the student to direct most of his or her attention to only the limb action requirements, because he or she can learn each part without attending to how to coordinate the two parts as a unit. After practicing each part independently, the swimmer can put them together to practice them as a whole unit, with his or her attention now directed toward both the temporal and spatial coordination demands of the arm and leg actions.

Skills that involve learning movement sequences lend themselves particularly well to the progressive part method. Researchers have demonstrated this for both laboratory and real-world skills. For example, Watters (1992) reported that the progressive part method was beneficial for learning to type an eight-key sequence on a computer keyboard. And Ash and Holding (1990) found that people learning a musical score on a piano benefited from a progressive part-practice approach. In this experiment, participants learned a musical score of twenty-four quarter notes, grouped into three sets of eight notes each. The first two sets were easy and the third set was difficult. Two types of the progressive part method were better than the whole method for learning to perform this musical score, for which performance was based on errors made, rhythmic accuracy, and rhythmic consistency. Of the two progressive part methods, the one that prescribed an easy-to-difficult progression tended to be better than the one stipulating a difficult-to-easy progression.

A key characteristic of the progressive part method is that it *takes advantage of the benefits of both part and whole methods of practice.* The part method offers the advantage of reducing the attention demands of performing the whole skill, so that the person can focus attention on specific aspects of a part of the skill. The whole method, on the other hand, has the advantage of practicing together the important spatial and temporal coordination of the parts. The progressive part method combines both of these qualities. Thus, the attention demands of performing the skill are under control, while the parts are put together progressively so that the learner can practice important spatial and temporal coordination requirements of performing the parts as a whole.

A CLOSER LOOK

The Simplification Method for Learning Three-Ball Juggling

An experiment reported by Hautala (1988) demonstrated that beginning juggling practice by using easier objects is beneficial for learning to juggle three balls.

The participants were boys and girls ten to twelve years old with no previous juggling experience. All of them practiced 5 min per day for fourteen days and then were tested for 1 min with the juggling balls.

The experiment compared four practice conditions:

1. Learners began practice using three "juggling balls" of three different colors.
2. Learners began practice using cube-shaped beanbags.
3. Learners followed a progressive simplification scheme:
   a. scarves of different colors
   b. beanbags
   c. juggling balls
4. Learners began practice using weighted scarves and then switched to the balls.

The results of the three-ball juggling test showed this:

- The beanbags practice condition led to the best test performance.

Note: The ball-juggling score for participants in the beanbag practice group was over 50 percent higher than those for the juggling balls group and the progression group, and over 100 percent higher than that of the group that practiced with weighted scarves and then beanbags before using the balls.

Simplification: Reducing Task Difficulty

For a complex skill, simplification is a method that makes either the whole skill or certain parts of the skill less difficult for people to perform. There are several ways to implement a simplification approach to skill practice. We will discuss six of these here. Each is specific to learning a certain type of skill. All of them involve practicing the whole skill, but simplify certain parts of the skill in various ways.

Reducing object difficulty. When a person is learning an object manipulation skill, one way to simplify learning the skill is to *reduce the difficulty of the objects.* For example, someone learning to juggle three balls can practice with bean bags. This reduces the difficulty of the task by involving objects that are slightly larger and easier to catch because they also conform to the shape of the hand. Because these objects are larger and deformable the person does not have to be as precise in positioning the hand to catch the object at the right moment However, the person still must follow the principles of juggling while learning to juggle the easier objects. We would expect early practice using easier objects to enable the person to learn these juggling principles, and then easily transfer them to juggling with more difficult objects. In fact, research evidence supports this approach to learning to juggle three balls (Hautala, 1988).

Reducing attention demands. Another way to reduce task difficulty is to *reduce the attention demands of the skill without changing the action goal.* This strategy reduces task difficulty by reducing task complexity. One approach to implementing this strategy is to provide physical assistance devices that allow the person to practice the goal of the skill but at the same time reduce the attention demands of the task. For example, Wulf and her colleagues (Wulf, Shea, & Whitacre, 1998; Wulf & Toole, 1999) found that people who used ski poles while they practiced the slalom ski simulator task learned to perform the task without ski poles better than people who practiced without ski poles. The poles allowed the performers to focus more attention on the movement coordination demands of the task. This was possible because of the reduced attention demands for the dynamic balancing component of the task, which resulted

A CLOSER LOOK

Training Wheels versus Balance Bicycles to Teach Bicycling

Training wheels have been used for many years to simplify the task of learning to ride a bicycle. Although training wheels seem to be an excellent example of the *simplification* approach to organizing part practice, one can also see elements of the *fractionization* and *segmentation* approaches in their use because the wheels enable the learner to practice the pedaling, steering, and braking components of the bicycling skill independent of the balance component. As proficiency increases on the other components, the balance component is gradually introduced and made more challenging by adjusting the height of the training wheels above the ground so that the bike can tilt more and more from side to side.

In recent years, the balance bicycle has become an increasingly popular way to introduce a child to bicycling. The balance bike is simply a bicycle without pedals or brakes. When the bicycle saddle is adjusted so that the child's feet can touch the ground, he or she can then propel the bike by essentially "walking" with it between the legs and can coast by lifting the feet off the ground. Interestingly, the first bicycle ever invented, by the German Karl von Krais in 1817, was referred to as a "swiftwalker" because it also had no pedals and so was propelled in the same way. In contrast to training wheels, the balance bicycle allows the learner to first practice the balance and steering components of bicycling independently of the pedaling and braking components.

Balance bicycle advocates argue that it is better to master the balance and steering components before adding the pedaling and braking components. Moreover, they argue that balancing and steering need to be practiced together because countersteering, which prevents the bicycle from tilting to the side, is integral to learning to balance on the bicycle. In other words, balancing and steering are interdependent (highly organized) components in bicycling. Some critics of training wheels have suggested that the wheels prevent the learning of countersteering, particularly if the height of the wheels is adjusted incorrectly, so that when the child rides without training wheels he or she has to unlearn and relearn how to steer. Whether this is true or not needs to be verified independently and whether training wheels or balance bicycles represent the best way to initially teach a child how to ride a bike is an open question at this point in time. Nevertheless, both methods are interesting examples of how part practice is commonly used to teach new skills.

from the poles enabling better body stability. It is also notable that in these experiments, transfer from performing with poles to doing so without the poles led to no appreciable reduction in performance level.

Physical therapy researchers have reported a method for the rehabilitation of gait that reduces the attention demands of gait while maintaining requisite gait movements. The method involves the use of a *body-weight support (BWS) system,* which is a device that controls the amount of body weight a person needs to support while ambulating either on a treadmill or over ground. As shown in figure 18.2, the patient is placed in a harness device that is attached to pulley systems that lift the patient so that the patient is supporting only a specified amount of his or her own body weight. The BWS reduces the attention demand of gait by providing external control of the patient's posture and balance.

An example of the use and effectiveness of the BWS for gait rehabilitation is a case study of two elderly women who continued to experience chronic gait disabilities as a result of a stroke more than two years earlier (Miller, Quinn, & Seddon, 2002). The BWS was used to systematically increase the amount of body weight controlled by the participants themselves for three sessions a week for six to seven weeks of gait training. During each session, the participants used the BWS for walking on a treadmill and overground. At the beginning of training, the BWS controlled 40 percent of the participants' body weight for each of three 5 min bouts of walking. Over the course of the training, the amount of body weight controlled was reduced to 20 percent and then to 0 percent. In addition, various treadmill speeds were included in the training sessions. Results showed that both women improved their overground walking

FIGURE 18.2 The Lite Gait body weight support system used in the study by Miller, Quinn, and Seddon. As it is shown here the system is being used for overground locomotion training; it can also be used with a treadmill. [Courtesy of Mobility Research, LLC, Tempe, AZ.]

in terms of technique and endurance. (To read a brief review of research involving BWS training and an experiment in which the system is successfully used with nonambulatory stroke patients, see Yagura, Hatakenaka, & Miyai, 2006.)

Reducing speed. A third simplification method is useful for the learning of complex skills requiring both speed and accuracy. *Reducing the speed* at which a learner first practices a skill can simplify practice. This approach places emphasis on the relative-time relationships among the skill components and on the spatial characteristics of performing the whole skill. Because a characteristic such as relative time is an invariant feature of a well-established coordination pattern and because people can readily vary overall speed, we would expect that a person could learn a relative-time pattern at a variety of overall speeds. By practicing at a slower speed, the learner would establish the essential relative-time characteristics of a coordination pattern. A commonly used teaching strategy by dance teachers for teaching a new type of dance (e.g., waltz) to beginners is to have them practice the sequence of steps at a slow speed and then increase the speed as they acquire the correct movement pattern of steps.

It is interesting to note that the training strategy of reducing the speed of a task also benefits the learning of asymmetric bimanual coordination tasks in which each arm performs different spatial-temporal patterns but with the same overall duration of time. What makes this interesting is that in the earlier discussion about the fractionization training strategy, that strategy also facilitated the learning of this type of bimanual task.

Evidence for the beneficial effects of the speed-reduction strategy was provided in an experiment by Walter and Swinnen (1992). Participants practiced an asymmetric bimanual coordination task that required them to use one arm to move a horizontal lever in a one-direction elbow-flexion movement while at the same time using the other arm to move a lever in a two-direction elbow-flexion-extension movement. One group practiced two sets of twenty trials at reduced speeds before practicing the task at the criterion speed. The other group practiced all trials at the criterion speed. Transfer test results showed that the reduced-speed training group learned to perform the task more accurately than the group that practiced the criterion speed only.

Adding auditory cues. Fourth, for skills having a distinct rhythmic characteristic, *providing auditory cues* that specify the appropriate rhythm works well to reduce task difficulty and facilitate a person's learning of the activity. This approach

LAB LINKS

Lab 18 in the Online Learning Center Lab Manual provides an opportunity for you to develop part-practice plans for a person who is learning or relearning a motor skill.

is especially interesting because it actually simplifies a task by adding an extra component to it. For example, musical accompaniment has been shown to assist Parkinson's disease patients with gait disorders while they practice walking. An example of research support for this simplification procedure was reported by Thaut et al. (1996). The researchers provided patients with Parkinson's disease with an auditory device that consisted of audiotapes with metronome sounds embedded in instrumental music to designate the rhythmic structure and tempo (i.e., speed) of the desired walking gait. The patients used the device as part of a three-week home-based gait-training program to pace their steps while walking. Compared to patients who did not use the device, the patients who trained with the auditory accompaniment showed greater improvement in their gait velocity, stride length, and step cadence. In addition, they accurately reproduced the speed of the last training tape without the assistance device. Since that initial study researchers have reported numerous experiments that support the use of auditory cues for gait therapy for Parkinson's disease patients as well as for patients with other movement disorders (e.g., Rochester, Burn, Woods, Godwin, & Nieuwboer, 2009; Schaffert, Janzen, Mattes, & Thaut, 2019; White, Wagenaar, Ellis, & Tickle-Degnen, 2009), and for therapy for reaching movements with a hemiparetic arm (Malcolm, Massie, & Thaut, 2009). However, more research is needed to determine which movement disorders are most likely to benefit from auditory cueing (Moumdjian, Buhmann, Willems, Feys, & Leman, 2018; Wittwer, Webster, & Hill, 2012).

Sequencing skill progressions. The fifth strategy is related to the progressive part strategy discussed earlier. It involves the *sequencing of skill progressions,* which means that a person practices variations of the skill being learned in a sequence from less to more complex or difficult until the skill itself is practiced. For example, in the discussion in chapter 1 of Gentile's taxonomy of motor skills, we considered the following task sequence to help young baseball players learn to hit pitches thrown by a pitcher: first, hit baseballs off a tee at the same height; next, hit balls off a tee at different heights; then, hit balls thrown by a pitching machine; and finally, hit balls thrown by a pitcher.

The task progression strategy is commonly referred to in the physical education teaching literature (e.g., Rink, 1998). Also included in this strategy is the use of *lead-up games or activities.* Although the task progression strategy has not received strong research support, results of an experiment reported by Hebert, Landin, and Solmon (2000) provided evidence that supported the learning benefit for an easy-to-difficult task progression of four distances from the net to practice the tennis serve, with the first distance at the service line, and then progressing back to serving from the baseline. Interestingly, this study included a progressive part training condition for the tennis serve in which the parts of the serve were practiced independently and gradually combined together. Although the progressive part condition yielded positive results, an advantage of the task progression strategy was that it led to high success rates for students of low, middle, and high skill levels. Notably, learners reported higher self-efficacy and higher motivation to learn and engaged in greater amounts of appropriate practice when they received easy-to-difficult practice compared to criterion practice from the service line. Similarly, Stevens, Anderson, O'Dwyer, and Williams (2012) reported that increased self-efficacy was associated with the beneficial effects of easy-to-difficult practice relative to difficult-to-easy practice on the learning of a stick balancing task.

Simulators and virtual reality. Finally, *simulators and virtual reality (VR) environments* are technical devices that provide ways to simplify certain features of a skill to help people learn skills. These devices have several advantages: people can practice skills without concerns about the cost of accidents or performance errors that would characterize practice in real environments; practitioners can control specific aspects of the performance environments more easily than in real environments; and people can often practice for longer periods of time and with more intensity than they could in a real environment.

Simulators are devices that imitate the environment, vehicles, machines, or instruments. For example, automobile and truck simulators are commonly used to train people to drive these vehicles. The military uses a variety of simulators, such as those for airplanes, tanks, and submarines, to train personnel who will operate these vehicles. In sports, simulators include devices such as pitching machines in baseball and softball, ball machines in tennis, and rebounders in basketball. In medicine, simulators range from very high-tech machines that enable surgeons to practice endoscopic and laparoscopic procedures to low-tech manikins that allow nurses to practice resuscitation skills or rehearse routine patient care procedures. Simulators can be used for training purposes by providing practice experiences before operating the actual device or by providing a practice situation in which certain attention demands are reduced. You read in chapter 13 about an example of the use of a simulator; see the Closer Look box discussion of the study by Weeks et al. (2003) concerning the use of an arm prosthesis simulator to train patients who would be fitted with an actual prosthetic arm.

Research investigations of the effectiveness of simulators have been more common for their use as training devices to help people learn to drive cars (e.g., Fisher et al., 2002), pilot airplanes and helicopters (e.g., Stewart, Dohme, & Nullmeyer, 2002), and perform surgical skills (Frank et al., 2018; Howells, Gill, Carr, Price, & Rees, 2008; Kalun, Wagner, Yan, Nousiainen, & Sonnadara, 2018) than for their use in sports contexts. In general, research results support the use of simulators as training devices, especially when they adhere to the similarity principles described in chapter 13 when we discussed why positive transfer occurs. For simulators, these principles concern the degree of similarity between the component parts of the tasks required by the simulator and the real device, between the performance contexts or situations, and between the cognitive processing characteristics.

VR environments simulate real environments through the use of two and three dimensional computer graphics. The virtual environments can be experienced in real time, which provides a realistic experience in that environment without being in the actual environment. You saw examples of the use of VR training strategies in chapter 13. It is also relevant to note that the training of visual search strategies that was introduced in chapter 9—an excellent example of a part-practice approach to learning—is frequently done in VR environments. Additional examples of VR training reported in the research literature have involved such diverse fields as sports, physical rehabilitation, surgery, and the military. These have included the following:

- Teaching a table tennis stroke (Todoroy, Shadmehr, & Bizzi, 1997), rowing (Ruffaldi et al., 2011), and a range of ball sports (Miles, Pop, Watt, Lawrence, & John, 2012)
- Creating individualized treatment exercises to augment dexterity task performance for poststroke patients (Merians et al., 2002)
- Rehabilitation of motor skills and daily tasks for people with upper limb movement loss due to brain injury (Levin, Weiss, & Keshner, 2015)
- Training people to regulate their walking pace so they could walk down a hallway and through doors that were continually opening and closing, at the time the doors were open (Buekers, Montagne, de Rugy, & Laurent, 1999)
- Assessing and training inexperienced powered wheelchair users (Harrison et al., 2002)
- Training reaching behaviors in children with cerebral palsy (Chen, Kang, Chuang et al., 2007)
- Training surgeons to perform laparoscopic surgery (Aggarwal, Grantcharov, Eriksen et al., 2006; Gallagher et al., 1999)
- Training submarine officers to perform various ship-handling tasks (Hays & Vincenzi, 2000)
- Training baseball batters to improve their batting performance (Gray, 2017)

In each of these situations, the use of a VR environment provided an effective means of practice to either prepare people to perform the skills in a real environment, or augment physical practice in a real environment.

In a review of the "state of the art" for VR applications in physical rehabilitation, Holden (2005) described available equipment, a scientific rationale for the use of VR in physical rehabilitation, and research that has investigated the effectiveness

A CLOSER LOOK

Virtual Reality Training to Step over Obstacles Improves Walking for Poststroke Hemiplegic Patients

Researchers and physical therapists reported a study in which they compared stepping over real or virtual objects on a treadmill as an intervention strategy for poststroke patients with hemiplegia (Jaffe, Brown, Pierson-Carey, Buckley, & Lew, 2004). The intervention was considered an alternative training technique with a goal of improving walking and decreasing the risk for falls and subsequent injuries.

Participants: 20 adults (8 females, 12 males; mean age = 61.5 yr) who had a stroke more than six months earlier (mean = 3.7 yr poststroke); had a diagnosis of hemiplegia; could walk independently; had an asymmetric gait pattern; and a short step-length (lower than 95th percentile of a normal step-length).

Training interventions: Participants were assigned to either a real or virtual training method. Training for both methods involved stepping over ten stationary objects while walking. Participants wore special "booties" that included contacts and switches for performance analysis purposes and for providing an audio tone to participants when they contacted an object. Each training session included twelve trials, which lasted approximately 1 hr. There were six sessions over a two-week period.

Real obstacle training: Participants wore a gait-belt and stepped over foam obstacles in a hallway. The obstacles were spaced at intervals of 15–22 in. The obstacles were 2 × 2 in. square and ranged in height and length based on participants' leg lengths (maximum height = height of inferior border of the patella; maximum length = height of trochanter minus one-half maximum obstacle height).

Virtual obstacle training: Participants, who were held in place by an overhead harness, walked at a self-selected speed on a motorized treadmill while holding onto handrails. They wore a head-mounted display that showed real-time images of the same objects used in the real-obstacle training procedure. The display also provided a lateral view of the participants' legs, which allowed them to observe the position of their feet as they walked, monitor their knee flexion, time their toe-off, and control their stepping height and length.

Results: Performance was assessed by ten outcome measures related to balance, walking velocity, cadence, stride length, endurance, and obstacle clearance. At two weeks posttraining, both groups showed improved performance compared to their pretest performance, but the virtual-reality-trained participants performed better on six of the ten measures.

Conclusion: Virtual reality training can be more effective than real-object training for improving the capability to step over objects as well as various walking characteristics for people with poststroke hemiplegia.

of VR in physical rehabilitation. The areas of study reviewed in physical rehabilitation include stroke rehabilitation, brain injury, Parkinson's disease, orthopedic rehabilitation, balance training, wheelchair mobility, and functional activities of daily living. From this review, Holden concludes that people with disabilities are capable of learning in VR environments and that this learning successfully transfers to real-world environments. In an important extension to these conclusions, You et al. (2005) found evidence that VR training resulted not only in improved locomotor recovery but also in neurological benefits. Their fMRI results showed that the VR training induced a reorganization of brain cortex activation from an abnormal ipsilateral to a normal contralateral activation in the sensory-motor cortex, which they described as playing an important role in the recovery of locomotor function for people with chronic stroke. More recently, Bohil, Alicea, and Biocca (2011) and Tieri, Morone, Paolucci, and Iosa (2018) have provided an update on the range of applications for VR training in rehabilitation.

A caution against using miming as a simplification method. A common practice in occupational therapy is to have patients mime task performance, or pretend they are performing a task. For example, rather than have a person reach for and grasp a glass of water and drink from it, the therapist asks the person to mime this complete action without the glass present. The problem with this approach is that different patterns of movement characterize the mimed and the real actions.

Mathiowetz and Wade (1995) clearly demonstrated these movement pattern differences for three different tasks for normal adults and adults with multiple sclerosis (MS). The three tasks were eating applesauce from a spoon, drinking from a glass, and turning pages of a book. The authors compared two different types of miming: with and without the object. For both the normal and the MS participants, the kinematic profiles for the three tasks revealed uniquely different characteristics for the real and the mimed situations.

Although this experiment and situation relate specifically to a specific patient population in a physical rehabilitation environment, the results have implications for all skill learning situations. When simplifying the practice of a skill, a therapist, teacher, or coach should have the person perform the natural skill. In each of the simplification methods described in the preceding section, this was always the case.

AN ATTENTION APPROACH TO INVOLVING PART PRACTICE IN WHOLE PRACTICE

Sometimes it is not advisable or practical to separate the parts of a skill physically for practice. This, however, does not mean that a learner cannot practice parts of the whole skill. It is possible to practice the whole skill, but focus attention on specific parts that need work. This approach provides both the advantage of part practice, where emphasis on specific parts of the skill facilitates improvement of these parts, and the advantage of whole practice, in which the emphasis is on how the parts of the skill relate to one another to produce skilled performance.

Both attention theory and research evidence support this attention approach. In Kahneman's model of attention, which was discussed in chapter 9, an important factor in attention allocation policy is called *momentary intentions.* When applied to a performance situation, this factor comes into play when a person focuses his or her attention on a specific aspect of the performance. Because we can manipulate our attention resources in this way, we can direct attention to a specific part of a skill while performing the whole skill.

An example of research evidence supporting the use of this attention-directing strategy for part practice is an experiment by Gopher, Weil, and Siegel (1989). Participants learned a complex computer game, known as the Space Fortress Game, that requires a person to master perceptual, cognitive, and motor skills as well as to acquire specific knowledge of the rules and game strategy. The player must shoot missiles at and destroy a space fortress. He or she fires the missiles from a movable spaceship, controlling spaceship movement and firing using a joystick and a trigger. To destroy the fortress, the player must overcome several obstacles, such as the fortress's rotating to face the spaceship to defend itself, protection of the fortress by mines that appear on the screen periodically and can destroy the spaceship if it runs into them, and so on (see Mané & Donchin, 1989, for a complete description of this computer game).

In the experiment, three groups received instructions during the first six practice sessions that emphasized a strategy requiring them to direct attention to one specific component of the skill. One group's instructions emphasized focusing attention on controlling the spaceship. The second group's instructions emphasized focusing attention on handling the mines around the fortress. The third group received spaceship control instructions for the first three practice sessions and then mine-handling instructions for the next three sessions. When the researchers compared the performance of these three groups against that of a control group that had not received any strategic instructions, the effectiveness of the attention-directing instructions was evident. As you can see in figure 18.3, the control group improved with practice, but not as much as the three instruction groups did. And the group that received two different strategies outperformed those that received only one.

These results provide evidence that attention-directing instructions can serve to establish a

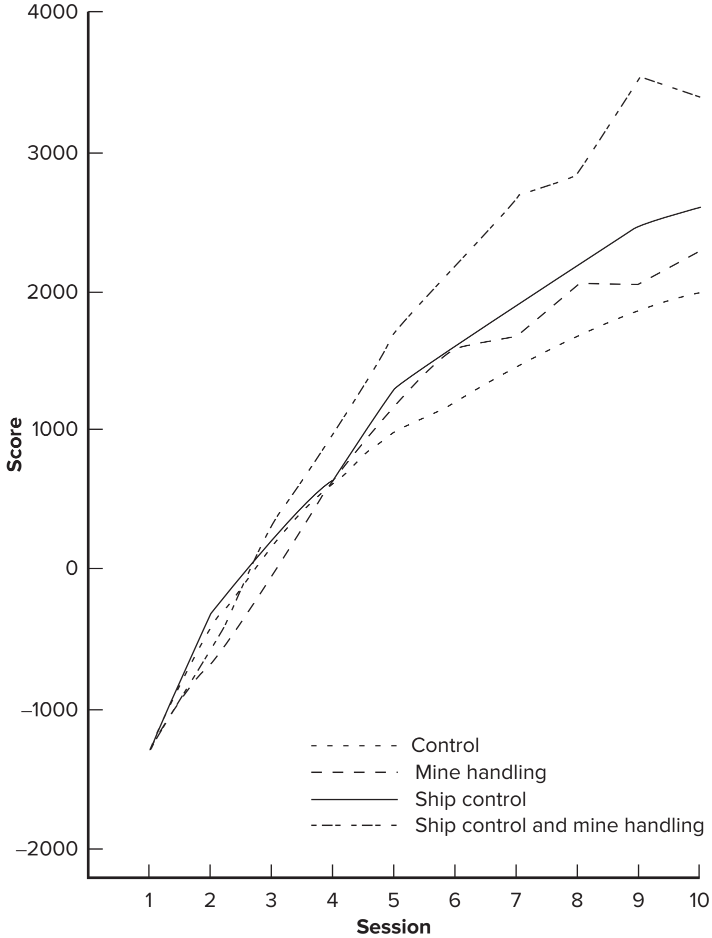

FIGURE 18.3 Results of the experiment by Gopher, Weil, and Siegel showing the change in performance on the computer game Space Fortress for attention-directing instructions related to specific parts of the skill. *Source:* From Gopher, D., et al. (1989). Practice under changing priorities: An approach to the training of complex skills. *Acta Psychologica, 71,* 147–177.

part-practice environment while allowing the person to practice the whole skill. And these instructions are more effective than having the person practice the skill without providing such strategies. An important connection needs to be made between the use of attention-directing instructions as a part-practice strategy and our discussions in chapters 9 and 14 about the focus of attention. It is notable that the attention-directing instructions for the computer game just discussed emphasized an external attention focus, which as we discussed, consistently results in better learning and performance than an internal focus. The extent to which attention-directing instructions as a part-practice strategy should emphasize an external rather than an internal focus remains a question for researchers to address.

SUMMARY

- Make the initial decision to use a whole- or part-practice strategy on the basis of the *complexity* and *organization* characteristics of the skill. Use a whole-practice strategy when the skill is low in complexity and high in organization; use a part-practice strategy when the skill is higher in complexity and is lower in organization.
- Parts of a skill that are interdependent in terms of their spatial and temporal performance

characteristics should be practiced together as a "natural unit"; parts that are relatively independent in terms of their spatial-temporal relationships can be practiced separately.

- Three methods of part practice were discussed:
  1. *Fractionization* is the practicing of an individual arm or leg of an asymmetric coordination task involving the arms or legs and then practicing them together.
  2. *Segmentation* is a progressive part method that involves practicing parts in sequence such that the first part is practiced until it can be performed at a certain performance level and then the next part is added and practiced, and so on until the skill is practiced as a whole.
  3. *Simplification* involves simplifying parts of the skill, or of the whole skill. We considered several different simplification methods, each of which is specific to certain types of skills or skill characteristics: reducing the difficulty of objects, reducing the attention demands, reducing the performance speed, adding auditory cues, sequencing task progressions, and using simulators and virtual reality (VR) environments.
- An effective whole-skill-practice strategy is to direct attention focus on a specific part of the skill while performing the whole skill.

POINTS FOR THE PRACTITIONER

- Before deciding whether to practice a skill as a whole or by parts, analyze the skill to identify its component parts.
- After analyzing a skill and identifying its parts, determine the degree to which the performance of any one part depends on the performance of the preceding part. When parts are characterized with this relationship, the parts should be practiced together as a unit rather than as separate parts.
- It is important not to assume that because parts can be identified they should be practiced separately; the performance dependence on preceding and following parts should always direct the decision concerning which parts to practice separately and which parts to practice together.
- When the parts of a skill follow a specific sequence of movements, the preferred way to engage in part practice is the progressive part method in which parts are practiced in sequence and become increasingly larger until the whole skill can be practiced in its entirety.
- When practicing the parts of a skill is not advisable or possible, consider ways to simplify the whole skill before engaging people in performing the skill as it would be performed in its real-world context.
- When the technology is available, simulator and virtual reality training provide excellent initial means of engaging people in practicing a skill before having them practice the skill as it would be performed in its real-world context.
- Directing attention to a part of a skill while performing the whole skill can be an effective way to correct errors for parts of a skill that should not be practiced as separate parts.

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STUDY QUESTIONS

1. (a) Define the term "organization" as it relates to the relationship among the parts (or components) of a complex motor skill. (b) Give an example of parts of a skill that demonstrate a high degree of organization. Indicate why you consider these parts to be highly organized.

2. (a) How can you decide whether people would learn a skill best if they practiced it as a whole or in parts? (b) Give a motor skill example to show how to apply these rules.

3. Describe examples of how practitioners can apply the part-practice methods of fractionization and segmentation to the practice of skills.

4. Describe three ways practitioners can apply the simplification method to the practice of skills.

5. What is virtual reality (VR) training? Why should it be considered related to the whole–part practice issue for learning motor skills?

6. Describe how you could apply an attention allocation policy factor in Kahneman's model of attention to practicing a motor skill as a means of implementing a type of part practice while practicing a whole skill. Give an example.

Specific Application Problem:

Select a motor skill that in your future profession you might help someone or a group of people learn.

(a) Describe this skill in terms of its component parts.
(b) Describe how each part relates to the part that precedes and/or follows it.
(c) You have been assigned to teach this skill to a group of people who have never performed it. Discuss how and why you would have them begin practicing the skill in parts or as a whole skill.