Application of Motor Learning Principles in Occupational Therapy

Janet L. Poole

Key Words: motor activity (physiology) • motor skills • movement analysis • movement patterns • occupational therapy services

The processes underlying skill acquisition depend on the nature of the task and the stage of the learner. In addition, feedback and practice are two potent learning variables when used appropriately in the instruction of motor tasks. Occupational therapists involved in the training and retraining of motor skills can benefit from knowledge of instructional methods used by coaches and physical educators. This paper reviews commonly accepted principles of motor learning and applies these principles to occupational therapy treatment. The stage of the learner, type of task, feedback, practice, and facilitation of skill acquisition are emphasized. Specific examples of how occupational therapists can use motor learning principles in treatment are given.

Variables Affecting Motor Learning

Schmidt (1988) defined motor learning as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for responding" (p. 346). The relatively permanent change in behavior is what differentiates learning from temporary improvements in performance. For example, after practicing a transfer several times, a patient may remember how to do it and thus exhibit an improvement in performance. If the patient cannot remember how to execute the transfer the next day, however, the task has not been learned. Thus, to estimate learning or relatively permanent changes, performance should be assessed again later (Schmidt, 1988).

Four factors influence motor learning: (a) the stages of learning, (b) the type of task, (c) feedback, and (d) practice. Although all of these factors must be considered by therapists in designing treatment programs, feedback...
and practice are thought to be the two most potent learning variables (Schmidt, 1988).

**Stages of Motor Learning**

Fitts and Posner (1967) defined three sequential stages involved in the motor learning process: cognitive, associative, and autonomous. In the cognitive stage, the learner tries to understand the requirements of the motor task. The learner has a vague idea of the task but is unsure of how to do it. Performance is usually inconsistent because the learner is trying many different strategies to do the task. Adams (1971) called this the verbal motor stage, because learners may need to verbalize the movement strategies. For example, a patient with an above-elbow amputation learning to use a prosthetic arm to grasp objects may initially use awkward whole-body positions while attempting the task. Verbalizing the sequence of repositioning the terminal device, positioning the elbow, and locking the elbow joint may be necessary to get the terminal device in the right position to grasp the object. During this first stage, the learner must begin to attend to the relevant information related to the skill (Gentile, 1972). In learning one-handed typing, a secretary who has had a stroke understands the task but needs to attend to new finger-key assignments.

In the associative stage, or intermediate stage, learners begin to refine their skills. Through continuous practice and repetition, the learner’s movements become more consistent and errors begin to decrease. During this stage, the structure of the practice period is an important consideration (Fitts & Posner, 1967). Error-free practice has been advocated by some theorists so that the learner develops an internal reference of correctness, or sensory feedback of the correct movement (Adams, 1971; Kottke, 1980). Incorrect practice of a task will require unlearning with interference in subsequent attempts to respond correctly (Adams, 1971; Lawther, 1977). Learners may use information about errors, however, to adjust subsequent movements that may increase the ability to generalize to new motor tasks. Edwards and Lee (1985) showed that subjects who were allowed to make errors while learning a task performed better on a novel task than did subjects who had practiced in an errorless learning situation.

Guidance is decreased as the learner begins to form appropriate associations between the movement plan and the sensory consequence, that is, the learner learns what feels right (Winstein, 1987). Feedback should be more precise, but it should start to decrease so that the learner becomes less dependent on it (Bilodeau & Bilodeau, 1958). Learners are encouraged to develop their own error-detection mechanisms (Winstein, 1987). With practice, the person with an amputation begins to learn what feels right, and the movements to operate the terminal device become more subtle and smooth. The secretary who has had a stroke begins to feel more comfortable with the new hand placement on the keyboard, and her performance becomes more accurate and consistent. It may take the secretary longer to develop automaticity than it would a new learner, because the old patterns of finger-key assignment may be detrimental to new learning (Schmidt, 1988).

In the final stage, the autonomous stage, the skill becomes automatic. The skill requires little, if any, cognitive processing, so it is less susceptible to interference from other ongoing activities or distractions in the environment. Once control of the prosthesis has become automatic, the patient can hold and eat an ice cream cone and walk down a crowded hall without crushing the cone. Instructions in this phase focus on a particular aspect of the skill. As long as some parts of the skill are automatic, a person can focus on other aspects of performance. The secretary will be able to look at the material to be typed rather than the keyboard, and practice would be focused on increasing speed without sacrificing accuracy.

**Types of Tasks**

Tasks can be classified along a continuum based on the type of environment in which they are performed (Gentile, 1972; Poulton, 1957). The environment may range from stationary for closed tasks to constantly in motion for open tasks. Critical features of the environment determine the spatial and temporal arrangement of a performer’s movements. For example, the shape, size, and type of handle on a cup will determine the configuration of the person’s hand prior to grasping the cup. Another example is how, when attempting to cross a busy street, a pedestrian’s path and speed of movements are constrained by the street terrain and by the speed, location, and number of moving vehicles.

In closed tasks, the critical features, such as objects, people, and the terrain, are stationary, and a performer is constrained by the spatial features of the environment. Quite different movements would be required to position a pencil for writing when the pencil is upright, lead side down, in a pencil holder than when it is lying flat on a desk. Timing is not specified in closed tasks, because they are self-paced and the learner decides the start, finish, and duration of the task. Many tasks in the home are closed. One usually stores grooming and hygiene materials in the same location, using consistent movement patterns to perform grooming tasks. The spatial features of the environment, however, may vary across trials. Gentile (1987) referred to tasks in which the objects or tools vary in position across time but are stationary during performance as variable motionless tasks. For example, eating, using the toilet, and some aspects of dressing are often routinely performed in places other than the home environment. Thus, one may have to deal with different styles of dishes or types of food, different heights of toilets, and...
different articles of clothing and surfaces available to use while dressing.

In **open tasks**, the supporting surfaces, objects, or people in the environment are in motion from one trial to the next (Gentile, 1972). The external environment controls the spatial and temporal features of the movement and makes predictive demands on the performer. If the environment is in motion but the motion remains the same across trials, the task is referred to as a **consistent motion task**. Stepping on to an escalator, lifting luggage from a conveyor belt, and sealing boxes moving on an assembly line are examples of consistent motion tasks. These tasks require mechanical devices that control a constant rate of motion in the environment. In a true motion task, the changes are not predictable, as in catching a fly ball, walking down a crowded hall, and driving a car. Successful performance of open tasks is determined by the performer's ability to adapt quickly to the changing environment.

Routine homemaking tasks may have an open element to them. For example, the presence of animals or young children in motion within the home could force predictive demands on the performer. The performer may have to anticipate the location of the children or animals to avoid tripping over them or, in some instances, the performer may have to catch the moving object. Many occupations, such as driver, crane operator, and food service worker, involve open tasks. Moving cars, trucks, and people and shifting loads make ongoing attentional demands on the performer.

The multitude of tasks that a person engages in during any given day vary along a continuum from open to closed. Outside the home, for example, in the workplace, school, or community environment, continual monitoring of the environment of both stationary and moving objects is necessary. The therapist's responsibility is to train the person to do the task in the environment most appropriate to that task. For closed and consistent motion tasks, practice should occur under fixed environmental conditions to develop movement consistency in attainment of the goal. Exposure to all possible sets of environmental conditions that one may encounter in real life is necessary to improve the performance of open and variable motionless tasks (Gentile, 1987; Spaeth-Arnold, 1981).

**Feedback**

Feedback, along with practice, is considered to be a potent learning variable (Bilodeau & Bilodeau, 1958; Salmoni, Schmidt, & Walter, 1984; Schmidt, 1988). Feedback may be intrinsic or extrinsic. **Intrinsic feedback** is inherent sensory information from receptors in the muscles, joints, tendons, and skin as well as receptors in the visual and auditory systems. Intrinsic feedback may occur during or after movement production. For example, a patient senses that his body weight is equally distributed over both legs while standing or sees that he has missed a cup with his hand. Conversely, **extrinsic feedback** is information from an external source that augments the intrinsic feedback. The external source may be a therapist or a device such as a biofeedback machine or a timer. Feedback is used in early learning to generate or modify each successive movement pattern. Later feedback helps compare the movement executed to the reference of correctness (Adams, 1971; Schmidt, 1975). The more sensory channels through which feedback is provided, the stronger the reference of correctness will be (Adams, 1971; Mulder & Hulstijn, 1985).

In the patient with impaired sensation, extrinsic feedback can be used to augment the absent or impaired intrinsic feedback. Studies have shown that motor learning can occur in the absence of intrinsic feedback. In the classic study by Rothwell et al. (1982), the deafferented subject learned new motor tasks while receiving extrinsic visual feedback through the use of an oscilloscope. When the visual feedback was removed, the subject could perform the tasks, but his performance decayed over time. The authors concluded that feedback was needed at some later point in time to update the central nervous system about the success and overall accuracy of the movement.

Two kinds of extrinsic feedback can be provided to learners: knowledge of results and knowledge of performance. **Knowledge of results** is verbal augmented feedback about movement outcome that is given after a movement (Schmidt, 1988). Knowledge of results provides information about errors, thus providing the learner with information on how to modify the movement on the next attempt. Examples used by therapists may be, “You landed too near the edge of the bed,” “Your shirt is on backwards,” and “You put your left leg in your right pant leg.”

**Knowledge of performance** is verbal feedback about the nature of the movement that is given after a response (Schmidt, 1988). Wyssen (1987) suggested that therapists use knowledge of performance more often than knowledge of results to provide information that the performer may not be aware of and that is directed toward correcting the movement pattern rather than just the movement outcome. Examples of knowledge of performance are, “You need to shift your weight more to your right leg,” “Your hand did not open soon enough,” and “Bend your knees and keep your back straight.”

Feedback of either type helps to facilitate and accelerate the learning process. Carr and Shepherd (1987a) and Gentile (1987) believed that therapists have not placed enough emphasis on verbal feedback for knowledge of performance and visual feedback for knowledge of results. Vision has been reported to play an important role in the acquisition and control of movement (Keele & Posner, 1968; Zelaznik, Hawkins, & Kisselburgh, 1983). Furthermore, when visual and verbal feedback were
eliminated, movement accuracy was impaired, even though augmented proprioceptive feedback, in the form of resistance, was provided (Williams & Stelmach, 1968). The amount and frequency of feedback is determined by the type of task the performer is engaged in and the stage of learning.

Practice

Practice is a second important variable in motor learning (Schmidt, 1988). Skill has been shown to increase directly in relation to the amount of practice (Newell & Rosenbloom, 1981). In the clinic, practice of motor skills is limited to time spent in the treatment session, which may be only 1 hr daily or less. Yet studies of skill learning show that it takes many trials to develop skill (Crossman, 1959; Kottke, 1980). Practice, however, involves more than mere repetition of a movement. It also means the formulation of “new plans of action to solve motor problems posed by the environment” (Whiting, 1980, p. 545).

Motor learning researchers have devoted considerable effort to determining the best way to structure practice (for a review, see Schmidt, 1988). One can manipulate the scheduling of rest periods, the order of the movements or skills practiced, the conditions of the task, or the amount of the task that is practiced.

Rest periods can be scheduled such that the rest time is less than the practice time, called massed practice, or greater than the practice time, called distributed practice. Massed practice is probably not appropriate in acute rehabilitation for patients who fatigue easily or who can control the pace of their daily schedule. Massed practice, however, may be appropriate in industrial or vocational rehabilitation, specifically, for the injured worker who will be returning to a work environment that demands task repetition or task performance over a certain time period.

The order of the tasks practiced can remain the same, called blocked practice, or differ, called random practice, across trials. In blocked practice, a patient might practice grasping styrofoam cups for several trials, then pick up coins for several trials; this pattern is then repeated. Random practice, which might require the grasping of a styrofoam cup, followed by the grasping of a coin, a coffee mug, and a pencil, requires the learner to be more alert, because the object grasped on each trial is different. The advantage of blocked trials is that performance improves faster than with random practice. The disadvantage is that the learner may not attend to the task because he or she knows what to expect (Lee & Magill, 1983; Shea & Morgan, 1979). Moreover, learning and recall have been found to improve more with random practice than with blocked practice (Shea & Morgan, 1979).

The conditions of the task may vary across trials, called variable practice, or may remain the same, called constant practice. Feeding oneself different textures of foods with different utensils, rising from different chair heights, and putting on different styles of front-opening upper extremity garments are examples of variable practice, whereas keeping the food, utensils, chair height, and style of garment the same across trials are examples of constant practice. Practicing under variable conditions has been shown to increase generalizability to novel situations (Shapiro & Schmidt, 1982). Because it is impossible for patients to practice every task they may encounter after discharge, variable practice may help with adaptation to a new situation.

The amount of a skill practiced can range from a subset of components constituting a task, called part practice, to practicing the task in its entirety, called whole practice. The logic behind part practice is that learning can proceed more efficiently, especially when the task is complex (Schmidt, 1988; Singer, 1980). The learner can spend less time on the parts of the task that were already mastered. Examples of part practice include practice with only one article of clothing, buttoning buttons on a button board, practicing shoe tying one step at a time, practicing typing with one hand in isolation of the other hand, and using simulators for driving and work-related tasks. Part practice appears to be effective when the task can be broken down into steps that are not temporally coordinated with each other (Wightman & Lintern, 1985). For example, the timing of the steps in tying a shoe or putting on a shirt is not crucial to performance of the task, whereas in walking or steering a car, many of the steps that can be isolated interact and are performed simultaneously.

At the heart of practice is the issue of transfer. Do the skills that patients learn in the clinic transfer to the home and work environments? For example, do patients actually use joint protection or body mechanics principles outside the clinic? Is the patient who is independent and safe getting into and out of the bathtub in the clinic also safe and independent at home? Stallings (1982) defined transfer as “the effect previous practice has on subsequent learning or performance” (p. 203). In this respect, transfer involves not only transfer from practice in the clinic to performance in the home but also transfer from one motor skill to another and from limb to limb. For transfer to occur, the learner must have adequate experience with the original task and conditions surrounding learning a movement. Practice must simulate the real-life performance situation as closely as possible (Stallings, 1982). This implies specificity of training or practice of the task under the same conditions under which the task will be performed. Therefore, if patients are to use correct body mechanics on the job, they should practice the techniques while actually doing the task. Thus, the use of an activity requiring prolonged tool use and overhead reaching to simulate an auto mechanic’s job may not necessarily enable the person to return to his or her job.
For most sports, the practice of drills or parts of a whole task in isolation does not transfer to the real game situation (Stammers, 1982; Wightman & Lintern, 1985). Likewise, the practice of isolated exercises for increasing weight bearing on a hemiplegic lower extremity did not result in more equal weight distribution during actual gait (Winstein, Gardner, McNeal, Barto, & Nicholson, 1989), and electromyographic biofeedback training on specific movements of the hemiplegic upper and lower extremity did not improve functional use of the extremity (Mulder & Hulstijn, 1988; Wolf & Binder-Macleod, 1983). Newell (1981) suggested that some breakdown of tasks, in which there are natural subtasks and in which timing is not crucial, may be appropriate for persons with brain damage. He recommended that part practice be used only to acquire the most basic component of a task and should be followed by whole practice in which the person concentrates on the component. When practicing only part of a task, the learner may have difficulty integrating the elements and timing in the whole task. These findings suggest the need for treatment programs to be more specific in terms of the environmental conditions and underlying processes. Ideally, therapy would be done in the work or hom-environment. A recent study by McCauley (1990) incorporated individualized on-the-job instruction in body mechanics with traditional lecture instruction. The subjects did improve in their use of body mechanics over a 4-week period.

Mental practice, or imagining task performance without any overt action, is another practice technique. Research indicates that mental practice is better than no practice at all but is not as effective as actual practice (Feltz & Landers, 1983; Weinberg, 1979). This type of practice has been found to activate cortical areas associated with the particular movement (Decety, Philippon, & Ingvar, 1988; Ingvar & Philipson, 1977; Roland, Larsen, Lassen, & Skinhøj, 1980). Carr and Shepherd (1987b) suggested that mental practice may be beneficial following a stroke, at which time the patient has very little muscular activity. Mental practice allows persons to practice on their own even before active muscle contractions can be activated.

Facilitation of Motor Skill Acquisition

In the initial stages of learning, it is extremely important that the learner understand the goal. The therapist can use verbal instruction, demonstration, or manual guidance to give the patient an idea of the movement. Videotapes or photographs can clarify understanding. The therapist's instructions, however, should focus on the important perceptual cues and essential aspects of the skills. In teaching correct lifting techniques, the therapist may instruct the patient to test the load and to assess the path and destination of the load before beginning the lift. A patient with a visual-field deficit may be cued to turn the head to the side before commencing a task. The patient with an amputation may be instructed to look for the flat surface of objects before deciding how to pre-position the terminal device on the prosthesis. For all tasks, relevant features of the environment could be enhanced with the use of color, markings, or a contrasting background. Typewriter keys could be color coded according to which finger is assigned to which key for the beginning one-handed typist. In addition, with open tasks, as the instructor identifies the relevant cues, the learner could observe the motion in the environment before attempting a task (Gentile, 1987; Spaeth-Arnold, 1981). For example, a person learning to steer an electric wheelchair might observe the events in a crowded hallway as the therapist points out people's walking speeds, door locations, and intersections where moving people may suddenly stop, turn, or emerge.

In initial learning, constant and blocked practice may be indicated to increase performance. The learner needs to practice the same movement a few times to get the idea of it. For example, transfers to the same chair can be practiced before proceeding to different heights or types. When training a confused patient, the therapist may also prefer to use a constant schedule. For example, dressing training might start with only one style of shirt, pants, and shoes. After a few days of practice with one particular style of clothing, the patient would need to practice with other styles.

Through trial and error and numerous attempts to complete the task, the learner begins to develop successful movement patterns. To facilitate learning, the movements should be practiced in whole rather than part, so that the movements are practiced in the context of the entire task (Schmidt, 1988). If learners accomplish the goal or execute the desired movement, they are encouraged to repeat the same performance. If the learner is unsuccessful, then feedback from the therapist regarding the general features of the movement should be given. In early learning, feedback should be given frequently so that the learner develops a reference of correctness instead of incorrect or compensatory movement patterns (Adams, 1971; Gentile, 1987; Kortke, 1980; Schmidt, 1975). Feedback should be delayed a few seconds after the movement is made so that the learner can process intrinsic feedback (Gentile, 1987).

Practice in the later stages of learning becomes more task dependent. Specificity of training and a constant practice format are often advocated for closed and consistent motion tasks in which the environment is stable and predictable. However, motor learning research shows that even for closed tasks, variable practice schedules improve learning and transfer (McCracken & Stelmach, 1977; Shapiro & Schmidt, 1982). Feedback in the later stages of learning should be precise but should become less frequent so that the learner becomes less dependent on feedback (Salmoni et al., 1984).
tent motion tasks, knowledge of performance is more appropriate, because the goal is successful goal attainment with the use of a consistent movement response (Gentile, 1987). For example, when training keyboard operators to reduce forceful, repetitive finger exertions, the therapist might provide feedback to not lift the finger so high off the keyboard.

In later stages of learning for open and variable motionless tasks, variable practice schedules under diverse environmental conditions are indicated (Siegel & Davis, 1980). The learner must develop flexibility and a repertoire of strategies to match changing and often novel environmental conditions. Therefore, the instructor must systematically change environmental conditions during practice to encompass all possible sets of constraints (Spaeth-Arnold, 1981). For example, mobility training should be done in empty hallways and sidewalks as well as in crowded hallways and sidewalks. Dressing should be done with all styles of clothing that the person normally wears, and patients should practice lifting objects of various sizes, shapes, and weights to and from different heights. For practice to be effective, Gentile (1987) recommended that the therapist change conditions after every two trials rather than after every trial. The second trial allows the learner to correct errors immediately. Feedback for variable motionless and open tasks should focus on how well the performer anticipated the environment and selected the movement pattern. Feedback about the prior movement is not valuable, because a new movement may need to be generated on the next trial. Automaticity is not possible with open and variable motionless tasks because there is always an element of uncertainty that must be monitored continually.

Summary

Principles of motor learning have much to offer occupational therapists in designing treatment programs aimed toward the learning or relearning of motor skills. Feedback, necessary for both the acquisition and the reacquisition of motor skills, depends on the stage of the learner. More feedback is needed in the early stages of learning than in the later stages. During the later stages, feedback should be more precise and should decrease in frequency. In addition, extrinsic feedback in the form of knowledge of performance or knowledge of results can be used to augment intrinsic sensory feedback. By providing information about how movements are executed (i.e., knowledge of performance) as well as the movement outcome (i.e., knowledge of results), the therapist gives the learner information about how to correct the movement pattern on the next attempt.

The findings from research on motor learning also support a functional approach to treatment in which movement patterns and components of tasks should primarily be practiced in relation to functional tasks. Traditional methods using verbal instructions to teach joint protection, body mechanics, or assistive device usage will probably not result in carryover to the home or work environment. Persons should be trained in the environment most appropriate to the type of task and to where the task will be performed in the real world. Recognizing that this suggestion is not always feasible to implement, therapists can use random and variable practice conditions in which the task or environment changes on each trial. These two conditions allow patients to practice and solve a wide variety of motor problems to facilitate generalization and transfer of motor skills to the home or work environment. ▲

Acknowledgments

I wish to thank Joan C. Rogers, PhD, William D. Stotz, PhD, George E. Carrell, PhD, and Carol A. Wood, PhD, for their many helpful suggestions during the preparation of this paper.

References


