Motor Learning and Occupational Therapy: The Organization of Practice

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This article addresses implications for the practice of occupational therapy when that therapy is guided by theories of motor learning. In occupational therapy, clients must learn or relearn motor skills through the use of activities. The occupational therapist must present activities in a manner that elicits the retention and transfer of the desired skills for use in functional settings. Therefore, the therapist should strive for acquisition conditions that facilitate retention and transfer of the learned skills. The processes that underlie motor learning should guide therapy. Three major factors that affect motor learning are environmental conditions, cognitive processes, and movement organization. Examination of the clinical implications of these factors, however, results in contradictory predictions regarding optimal practice conditions for motor skills. This article explores the successful integration of these factors and its application in occupational therapy practice. It is suggested that increasing the difficulty of the learning context during practice is beneficial for retention.

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Factors That Influence Motor Learning

Movement Organization

In the past, motor learning theories focused on descriptions of movement organization, stressing the coordination of the neuromuscular systems that control movements (Adams, 1971, 1977; Arbib, 1985; Schmidt, 1975). From this perspective evolved the theory that movement patterns are stored in memory as a schema or an abstraction of the general characteristics of a movement (Schmidt, 1975). However, Schmidt (1988) referred to the schema as a generalized motor program that serves as the memory representation for a class of movements, rather than for any one action or movement.

A movement class is defined by the invariant characteristics of actions. Invariant characteristics are “aspects of movements that appear to be fixed even though other, more superficial features can change” (Schmidt, 1988, p. 266). When a group of actions have common invariant characteristics, they are considered to be in the same movement class and are therefore represented in and controlled by the same generalized motor program. For example, signing one’s name is a generalized motor program. Whether one signs on paper or on a blackboard, using hands or feet, the guiding rules in this action are identical. The pattern of the signature or the shape of the letters, which will be similar in any of these actions, are invariant, yet the size of the letters and the specific muscles used vary.

Several different movement characteristics have been proposed to be the invariant characteristics of a motor program, such as the relative timing of the components of the action, the relative force produced by the components of the action, the sequence of events involved in the action (Schmidt, 1988), and spatial configurations (Bernstein, 1967). Currently, however, there is no general consensus concerning the characteristics of motor programs (e.g., Gentner, 1987, 1988; Heuer, 1988; Heuer & Schmidt, 1988). Furthermore, the generalized motor program theory has been criticized for its failure to prove the existence of additional invariant features (Horak, 1991; Poole, 1991b).

From Schmidt’s (1975; 1988) viewpoint, the strength of a generalized motor program is directly related to the variability in practice of different tasks that belong to the program’s movement class. For example, practicing transfer to different types of chairs allows the client to practice the motor program of transferring to a chair, whereas the timing of the action, the force produced by the muscles during the motion, and the size of the motion (the spatial configurations) differ according to the width, height, and shape of the chairs. Hence, Schmidt predicted that variability in practice is beneficial for retention and transfer of a motor skill. Catching balls of varying size or grasping objects of different shapes are two other examples of variable practice.

Studies investigating the effects of practice variability (e.g., Kerr, 1982; Magill & Reeve, 1978; McCracken & Stelmach, 1977; Newell & Shapiro, 1976; Wrisberg & Ragsdale, 1979) compared constant practice of a single task to variable practice in either a predictable or unpredictable presentation order. Studies in which variable practice tasks were presented in a predictable order found limited support for the theory that variability enhances retention and transfer (Kerr, 1982; Magill & Reeve, 1978; Newell & Shapiro, 1976). Studies in which variable practice was presented in an unpredictable order (Mc Cracken & Stelmach, 1977; Wrisberg & Ragsdale, 1979), however, did support the theory.

Environmental Factors

Environmental factors influence motor learning. The therapist must consider the nature of the environment because different environmental factors elicit different motor reactions (Gentile, 1972, 1987). To be successful, movements should correspond with certain factors of the environment. For example, the movement of picking up a cup to drink must be adapted to the environmental factors of the shape of the cup, its distance from the person, and the volume of liquid. The object, in this case the cup, determines the spatial arrangement of the movement. In some cases, timing of the movement is important, such as in the act of catching a ball. The goal of the action determines the environmental factors (regulatory conditions) that are critical for performance (Gentile, 1972, 1987).

Motor skills may be classified according to their spatial and temporal environmental factors (Gentile, 1972, 1987). When temporal environmental factors are stationary, only the spatial factor of the movement is controlled by the environment. For example, the spatial factors of picking up a newspaper are different for lifting a Sunday newspaper than for lifting a weekday newspaper. Timing is not specified—lifting the paper is a self-paced action. Tasks in which temporal environmental factors remain stationary and fixed from trial to trial are termed closed tasks. Tasks in which the temporal factors of the environment are stationary but the spatial factors of the task, such as the size or location of objects, vary from trial to trial, are called variable motionless tasks. These include walking on different surfaces, picking up a cup from different locations on a table, and buttoning a shirt with different types of buttons.

When environmental factors include objects or persons that are moving, both spatial and temporal factors of the movement are determined by the environment. For example, when catching a ball or stepping onto an escalator, a person needs to predict where the object will be. Tasks in which these environmental factors change from trial to trial are termed open tasks. For some tasks, the pace of the movement is constant while the environment is moving. These tasks, termed consistent motion tasks,
are associated with mechanical devices such as escalators and assembly line belts.

Skill acquisition, according to Gentile (1972, 1987), involves two stages: (a) trial and error, in which the movement patterns are not consistent; and (b) task dependent, in which the four types of tasks are learned differently and therefore should be taught differently. As practice progresses in closed and consistent motion tasks, movement patterns are refined and retained. The movement pattern should become consistent because the environmental conditions are static (Higgins & Spaeth, 1972; Hobart, Vorro, & Dotson, 1978). Therefore, Gentile (1972, 1987) recommended using a predictable environment to teach persons to develop a consistent motor pattern in response to stationary input.

As practice progresses in the open and variable motionless tasks, movement patterns should become diversified. The client must respond to the varied environmental stimuli (Higgins & Spaeth, 1972; Hobart et al., 1978). Therefore, Gentile (1972, 1987) recommended teaching open and variable motionless tasks in an unpredictable, changing environment to develop diversification of the motor pattern.

Cognitive Processes

Motor learning theories have been criticized for their tendency to focus on internal neuromuscular movement organization while underestimating the importance of cognitive processes in retention and transfer of motor behavior (Battig, 1979; Lee & Magill, 1983b; Salmoni et al., 1984). Learning theory suggests that skill acquisition in unpredictable environmental conditions is beneficial for memory and transfer (Battig, 1979; Craik & Lockhart, 1972; Shea & Zimny, 1983; Tulving, 1979). Battig (1979) claimed that presenting several motor tasks together in certain contexts can facilitate cognitive processes beneficial to memory improvement. He termed the difficult learning context, such as an unpredictable situation, a context with high contextual interference. Performing a motor task in a difficult learning context forces the client to use multiple and variable processes to overcome the difficulty of practice (Battig, 1979; Shea & Zimny, 1983; 1988). Despite its slowing of the acquisition phase, performing in a difficult context leads to the development of more elaborate and distinctive memory representations of the movements practiced, which is beneficial for retention (Battig, 1979; Shea & Zimny, 1983; 1988). The teacher can create high contextual interference by presenting trials of several tasks in a random order. That is, if each task is assigned a different letter, the order of tasks might be ABACBACABBC. For example, random practice with transferring to a chair would involve introducing a different chair to the client in different trials.

Lee and Magill (1985) suggested that the presentation of motor tasks in an unpredictable context causes the client to forget certain aspects of the way he or she performed the tasks before. The time lapse between the presentation of different tasks (e.g., different chairs) causes the client to forget the way he or she performed the movements before, forcing the client to reconstruct movements for each subsequent attempt. As a result, further practice is imposed on the client, which facilitates retention. Several studies supported this reconstruction view (Lee & Magill, 1983a, 1985; Magill, Meeuwsen, Lee, & Mathews, 1992; Shea & Wright, 1991). The findings of Del Rey, Wughalter, and Carnes (1987) did not support Lee and Magill's (1983b, 1985) explanations, because the interfering activity they used to facilitate this type of forgetting did not influence retention or acquisition.

The easy learning context, termed one with low contextual interference, such as a predictable situation, does not force the client to use elaborate encoding processes, leaving weaker memory representations of the movements practiced (Battig, 1979; Shea & Zimny, 1983; 1988). As a result, although low contextual interference may speed the process of acquiring a skill, it does not help retention to the same extent as high contextual interference. Low contextual interference can be created by presenting tasks in a blocked order, so that practice of the first task must be completed before the client advances to the second task, and so on (i.e., AAABBBCCCD). For example, in the activity of transferring to a chair, the client would practice transferring to a specific chair repeatedly until that task was mastered. Only then would the client practice transferring to another type of chair, and so on.

The feedback given to the client about the consequences of a movement, such as the extent to which the intended goal was achieved, can be referred to as knowledge of results (Sage, 1984; Schmidt, 1988). Knowledge of results can be telling the client "You burned the egg," "You put the peg in the right hole," "You missed the target by 2 inches," or "You buttoned your shirt wrong." Jarus (1988) and Lee and Magill (1983b) suggested that the effect of the level of knowledge of results during the acquisition phase may be similar to the effect of high contextual interference. Several studies have found that clients given constant knowledge of results in the acquisition phase do not do as well in the retention phase, when knowledge of results is eliminated, as do clients given less frequent knowledge of results in the acquisition phase (Baird & Hughes, 1972; Ho & Shea, 1978; Jarus, in press; Schmidt, Young, Swinnen, & Shapiro, 1989; Weinstein & Schmidt, 1990; Wulf & Schmidt, 1989). Schmidt (1988) stated that knowledge of results can be viewed as a crutch that guides performance. Under conditions with limited knowledge of results, the client is forced to rely on other relevant cues of the task, such as sensory feedback, to improve performance (Salmoni et al., 1984; Schmidt, 1988). The client can subsequently perform the acquired task without knowledge of results.

This reasoning is consistent with the contextual vari-
tery hypothesis (Battig & Shea, 1978). That is, predictable practice in a blocked order, or with constant knowledge of results, is beneficial for acquisition, yet detrimental to retention. Unpredictable practice in a random order, or with lower knowledge of results frequency, is detrimental to acquisition, but beneficial for retention and transfer. Thus, the level of contextual interference and the level of knowledge of results during acquisition of motor skills influences the abilities to retain the learned material and to perform a transfer task (Battig, 1979; Magill & Hall, 1990).

Discussion

Both Schmidt's (1988) generalized motor program theory and the contextual interference effect theory address the concept that variability in practice is related to improved retention and transfer. According to Gentile (1972, 1987), however, the acquisition of motor skills depends on the type of task being learned. Therefore, it is relevant to compare the concepts of variability in practice, practice schedule, and task classification, and their respective implications for clinical practice.

Variability in Practice and Practice Schedule

Schmidt (1975, 1988) made no predictions about the practice schedules that can be developed for variability in practice. In the traditional approach to testing the practice variability hypothesis, one group (the constant group) learned only one task, whereas the second group (the variable group) learned several tasks. Both groups had the same total number of trials. The number of tasks practiced by subjects differed (i.e., the amount of variability differed), and little or no attention was given to the order of the tasks (i.e., schedule of practice). In the contextual interference approach, however, the number of tasks was held constant for all clients (i.e., the amount of variability constant) but the order in which these tasks were presented (i.e., schedule of practice) varied. That is, one group learned several tasks in a random order, whereas the other group learned the same tasks in a blocked order.

Several studies (Lee, Magill, & Weeks, 1985; Turnbull & Dickinson, 1986; Wulf & Schmidt, 1988) have tried to assess whether the advantages of variability in practice result from generalized motor program formation or from enhanced information processing (caused by higher contextual interference), but these studies were either inconclusive or involved questionable experimental designs (Magill & Hall, 1990). There is apparently insufficient empirical evidence of the relationship between variable practice and practice schedule.

Magill and Hall (1990) hypothesized that the contextual interference effect differs for skill variations controlled by the same or different motor program. Accordingly, when the skill variations to be learned require different motor programs, manipulating the practice schedule creates different levels of contextual interference, which results in varying retention and transfer effects (i.e., the higher the level of interference, the better the effect). Similarly, when the skill variations involve parameter modifications of the same motor program, the contextual interference effect will not be found. For example, if a person practices throwing a ball at a target and uses three different throwing patterns, such as overhand, underhand, and sidearm, then three different motor programs are involved and the contextual interference effect would be found (Magill & Hall, 1990). However, if only one throwing pattern is used but three different ball speeds are practiced, then only one motor program is involved although the overall limb speed parameter must be modified to produce the different ball speeds. In this case, the contextual interference effect would not be found (Magill & Hall, 1990). This hypothesis was explored by Magill and Hall (1990) and requires further research.

Practice Schedule and Task Classification

The effects of blocked versus random practice have been studied considerably in the past decade (Magill & Hall, 1990). However, researchers who tested the premise of contextual interference theory in motor learning (Del Rey, 1982; Goode & Magill, 1986; Lee & Magill, 1983b; Young, Cohen, & Husak, 1993) used either a closed task or an open task exclusively. None of these studies investigated whether the effect of contextual interference differs between open and closed tasks. Studies in which the subjects learned a closed task (Shea & Morgan, 1979; Young et al., 1993) supported the contextual interference theory. Subjects in the group that practiced variations of a closed task in random order retained the task better than subjects in the group that practiced variations of a closed task in blocked order. Studies in which the subjects learned an open task (Del Rey, 1982, Del Rey, Whitehurst, & Wood, 1983; Del Rey, Whitehurst, Wughalter, & Barnwell, 1983; Del Rey, Wughalter, Du Bois, & Carnes, 1982; Del Rey, Wughalter, & Whitehurst, 1982) partially supported the contextual interference theory. Subjects who learned an open task in the random group did not always differ significantly from subjects who learned the task in the blocked group in their ability to retain the task.

To differentiate between the effects of contextual interference on the two types of tasks, a study must include both open and closed tasks, which can be presented under conditions of either low (blocked practice) or high (random practice) contextual interference. Holding all other factors constant will enable an investigation of the interaction between contextual interference and motor tasks of different classifications.

In a study that manipulated both the task classification and the contextual interference, subjects performed
a tracking task by moving their heads as they watched a 16-in.-computer-generated video display containing a cursor and a target (Jarus, 1988). The subject, who controlled the cursor by performing head movements, had to position the cursor in the target. In the open task, the target was in motion throughout the 5-sec trial. In the closed task, the target remained stationary. Three target locations were provided for both the open and closed tasks, to enable manipulation of the practice schedule. The subjects were divided randomly into four groups: open task—random order, open task—blocked order, closed task—random order, and closed task—blocked order. Results indicated that the high level of difficulty encountered when practicing the open task (in both random and blocked order) created high contextual interference, which is beneficial for retention and transfer (Jarus, 1988). Subjects who learned the open task appeared to be less dependent on the context in which the initial encoding occurred. It seems that the open task better prepared subjects to develop movement strategies or patterns in an unpredictable environment, allowing better retention and transfer to a new task. The closed task facilitated the development of fixed movement patterns, which resulted in inflexibility when a new task was encountered (Jarus, 1988).

These findings illustrate that there is no unique method of creating high contextual interference to facilitate retention and transfer. In addition to presenting tasks in an unpredictable order or with lower knowledge of results frequency, open tasks, in which critical factors in the environment are moving, can also create high contextual interference. That is, predictable practice, such as practice in a closed environment, in a blocked order, or with constant knowledge of results, or practice in a closed environment in a random order, or with lower knowledge of results frequency makes contextually dependent to acquisition and transfer, whereas unpredictable practice in an open environment, in a random order, or with lower knowledge of results frequency is detrimental to acquisition but beneficial for retention and transfer.

Clinical Implications

Contextual variety, open environment, and low knowledge of results frequency apparently facilitate cognitive-motor functioning during motor skill acquisition, thereby enhancing retention and transfer. Open tasks, unpredictable schedules, and limited knowledge of results require clients to adapt strategies and solve problems, which demand greater cognitive effort. Such activities facilitate retention and transfer of the acquired skill, because clients are forced to draw on information other than knowledge of results and must either develop an elaborate encoding process or reconstruct movement plans for each practice trial.

For example, difficulty can be increased by teaching an open task. Throwing bean bags at a target can become an open task if the target or the client is placed on a moving scooter. Climbing the stairs can become an open task if practiced on moving escalators. Throwing a ball to the client is an open task whose unpredictability can be increased if the client sits on an equilibrium board. Using a wheelchair in a busy corridor rather than an empty one is an open task.

During treatment, the therapist should try not only to present open tasks but also to organize the session so that several tasks are learned simultaneously and randomly, avoiding repetitions. For example, the session could involve throwing a ball to the client from different angles, asking the client to throw bean bags to several targets, practicing transfers from a wheelchair to a bed from different angles or to beds of different heights or firmness, or alternating between practicing activities of daily living and eye-hand coordination. The therapist can make the client do different tasks during each trial, alternate tasks, and introduce interfering activities that cause the client to forget the solutions so that the client must reconstruct the solutions when he or she tries the task again. Although this random presentation may be detrimental to performance, research suggests that it is beneficial for retention and transfer of the acquired task (Magill & Hall, 1990). The exception to this guideline might be in the very early stages of practice, when the client is just learning the basic concept of the task. At this time, blocked practice might be slightly more effective than random practice (Shea, Kohl, & Indermill, 1990). Once the client can perform the movement at all, random practice can be initiated (Schmidt, 1991).

Educating clients about these principles can heighten their understanding that these types of activities are beneficial for their long-term treatment goals. Accordingly, the clients may be less frustrated by a challenging or difficult therapy session.

Conclusion

Knowledge of effects of changing the order of presentation of different motor tasks, based on the different motor learning theories reviewed, can be used to facilitate retention and transfer of motor skills. Occupational therapists may use this information when planning treatment. The treatment goal should not necessarily be to achieve the most effective performance during therapy, but to maximize retention and transfer of the acquired skill. When the treatment goal is to enhance motor skill retention or transfer, increasing the difficulty of the learning context during practice is beneficial. Increased difficulty can be achieved by teaching an open task, presenting tasks in a random order, or providing infrequent knowledge of results.

Use of difficult practice contexts in occupational therapy is beneficial for the treatment process. In addition, such situations correspond more closely to the
kinds of everyday situations clients encounter, which are the core concern of occupational therapy (Breines, 1986; King, 1978; Meyer, 1977). This teaching method might support the fundamental assumptions of occupational therapy, which suggest that the focus of treatment should be the types of activities encountered in daily life (Dijoseph, 1982; Katz, 1985; King, 1978). These activities usually require the ability to respond to unpredictable events on the basis of limited information.

References


Quarterly for Exercise and Sport, 54, 340–345.
interference in motor-skills acquisition. Journal of Experimental
Psychology: Learning, Memory, and Cognition, 9, 730–746.
skill acquisition? In D. Goodman, R. B. Wilberg, & I. M. Frank
(Eds.), Differing perspectives in motor learning, memory, and
control (pp. 3–22). Amsterdam: North Holland.
practice schedule on testing schema theory predictions in
factors in a sensory processing model. American Journal of
Occupational Therapy, 40, 103–110.
interference effect in motor skill acquisition. Human Movement
Science, 9, 241–289.
(1992). Is the contextual interference effect in motor skill
learning a spacing effect? Unpublished manuscript.
practice in learning and retention of a novel motor response.
Perceptual and Motor Skills, 46, 107–110.
Behavior, 9, 193–201.
American Journal of Occupational Therapy, 31, 639–642. (Re-
printed from Archives of Occupational Therapy, 1922, 1, 1–10.)
York: Raven.
and theoretical knowledge of motor control and learning.
American Journal of Physical Medicine, 63, 225–244.
Newell, K. M., & Shapiro, D. C. (1976). Variability of prac-
tice and transfer of training: Some evidence toward a schema
Poole, J. L. (1991a). Application of motor learning principles
in occupational therapy. American Journal of Occupational
Therapy, 45, 531–537.
AOTA self study series. Neuroscience foundations of human
performance (pp. 1–23). Rockville, MD: The American Occupa-
tional Therapy Association.
Knowledge of results and motor learning: A review and critical
behavioral emphasis (2nd ed.). Champaign, IL: Human
Kinetics.
tical therapy. In M. J. Lister (Ed.), Proceedings of the II STEP
Conference on Contemporary Management of Motor Control
Problems (pp. 49–63). Alexandria, VA: Foundation for Physical
Therapy.
Schmidt, R. A., Young, D. E., Swinnen, S., & Shapiro, D. C.
(1989). Summary knowledge of results for skill acquisition: Sup-
port for the guidance hypothesis. Journal of Experimental Psy-
interference: Contributions of practice. Acta Psychological
(ams), 73, 145–157.
effects on the acquisition, retention, and transfer of a motor
skill. Journal of Experimental Psychology: Human Learning
and Memory, 5, 179–187.
motor retention. Research Quarterly for Exercise and Sport, 62,
293–301.
and learning movement information. In R. A. Magill (Ed.),
Memory and control of action (pp. 345–365). Amsterdam: North Holland.
in motor representation. In O. G. Meijer & K. Roth (Eds.),
Complex motor behavior: The motor–action controversy (pp.
physical dysfunction (2nd ed.). Baltimore: Williams & Wilkins.
Tulving, E. (1979). Relation between encoding specificity
and levels of processing. In L. S. Cermak & F. I. M. Craik (Eds.),
Levels of processing in human memory (pp. 405–428). Hills-
dale, NJ: Erlbaum.
Trombly, S. D., & Dickinson, J. (1986). Maximizing variabil-
ity of practice: A test of schema theory and contextual inter-
ference theory. Journal of Human Movement Studies, 12,
201–213.
of knowledge of result enhances motor skill learning. Journal of
Experimental Psychology: Learning, Memory, and Cognition,
16, 677–691.
Schmidt’s schema theory: Development of a schema rule for a
Facilitation in retention and transfer through schema formation
or context effects? Journal of Motor Behavior, 20, 135–149.
Wolf, G., & Schmidt, R. A. (1989). The learning of general-
ized motor programs: Reducing the relative frequency of knowl-
dge of results enhances memory. Journal of Experimental
interference and motor skill acquisition: On the processes
that influence retention. Human Movement Science, 12,
577–600.