Perceptual and Motor Skills, 2005, 100, 1107-1113.

EFFECTS OF SPECIFIC VERSUS VARIABLE PRACTICE ON THE RETENTION AND TRANSFER OF A CONTINUOUS MOTOR SKILL[1]

ROBERT J. HEITMAN, STEVEN F. PUGH, JOHN E. KOVALESKI,
PHILLIP M. NORELL, AND JAMES R. VICORY

University of South Alabama

Summary.—The effects of specific versus variable practice on retention and transfer was investigated. 30 participants were randomly assigned to one of three practice conditions. The variable speed group practiced on a pursuit rotor task at three different speeds (60, 45, 30 rpm) which were randomly distributed but equal in number for 30 10-sec. trials on Day 1. The Specific Practice group performed all 30 10-sec. trials at 45 rpm on Day 1. On Day 2, all groups performed 15 trials at the 45-rpm retention speed and 15 trials at the 75-rpm transfer speed. The Control group only performed on Day 2. Analysis showed the Specific Practice group had significantly higher scores on Day 1. On Day 2, the Specific Practice group had significantly higher retention scores and the Variable Practice group had higher transfer scores. Continuous motor skills might be practiced differently depending on the environmental context in which the skill may be used.

When teaching motor skills, both therapists and educators strive to apply the best practice techniques. In the instructional environment, the way practice is organized is important because it significantly affects magnitude of skill transfer. Schmidt (2003), in a historical review of motor schema theory, made suggestions for studies concerning schema learning and transfer. He stated that specificity of learning needed to be addressed in a new generation of motor learning investigations on the generalized motor program. Determining whether anything specific was learned about practiced movements or whether practice only contributed to a larger class of generalized movements was an issue of concern.

Traditionally, two opposing views have been posited in an effort to explain the magnitude of transfer effects. The earliest view was termed the specificity of learning principle (Henry, 1960; Adams, 1987; Shea & Kohl, 1990). Adams (1971) developed a closed-loop theory of motor skill acquisition which emphasized specificity in learning. His theory was error-centered and used error detection, correction, and knowledge of results to develop a perceptual trace of a specific movement. Essential to the development of a perceptual trace is the detection and labeling of errors related to a specific motor response rather than a class of movements (Stelmach, 1982).

[1]Please address correspondence to Dr. Robert Heitman, Department of Health, Physical Education, and Leisure Studies, 307 University Boulevard North, University of South Alabama, Mobile, AL 36688-0002.

In contrast, the variability of practice hypothesis states that, rather than remembering specific sensory consequences, learners use feedback to establish certain rules or schema (Sherwood & Lee, 2003). The development of schema enables the learner to establish a generalized motor program so the learner can generalize to a whole classification of skills rather than a specific motor skill. This theory hypothesizes that transfer is based on learned rules rather than memory about specific motor skills. According to the variability of practice hypothesis, motor skills practiced under varying conditions strengthens the generalized motor program which is conducive to promoting greater retention and transfer to novel situations.

One variable of concern in studying the interaction between variability of practice and task specificity may be the type of motor skill employed as the criterion measure. Traditionally, studies involving variability of practice effects on transfer have used discrete skills (e.g., Goode & Magill, 1986; French, Rink, & Werner, 1990; Brady, 1997; Jarus, Wughalter, & Gianutos, 1997). Studies examining specificity of practice have primarily used continuous type motor skills (e.g., Proteau, Tremblay, & DeJaeger, 1998; Coull, Tremblay, & Elliott, 2001; Proteau & Carnahan, 2001).

Discrete skills are generally considered to occur too rapidly to allow intrinsic feedback to make corrections during the movement. Rapid movements of a short duration are thought to be preprogrammed and carried out in an open loop via the generalized motor program without the aid of sensory feedback. Since Adams' closed-loop theory is based on the assumption that afferent feedback is used to monitor movements, it is most useful in describing how people control continuous motor skills (Schmidt & Wrisberg, 2000). There is evidence that, if a movement pattern is carried out long enough, feedback is used to monitor the movement (Stelmach, 1973; Christana, Lambert, & Fischman, 1982; Hammerton, 1989). Tracking tasks, such as a rotary pursuit, are generally considered to be under closed-loop control and thus monitored via sensory feedback (Schmidt & Wrisberg, 2000). Since feedback plays a more prominent role in the specificity of learning hypothesis, it might be hypothesized that specific practice on a continuous motor skill would promote retention and transfer more than variability of practice. This study assessed whether variable practice or specific practice best affects retention and transfer on a continuous motor skill.

METHOD

Subjects

Thirty college age students volunteered and participated in the study (15 men and 15 women; M age = 21.3 yr., SD = 2.6; M height = 172.0 cm., SD = 8.6). Each subject was informed of the nature and purposes of the study according to institutional guidelines before giving signed consent to participate.

Design

The experimental design employed to examine the effects of Specific versus Variable practice was a 2 × 3 factorial design with repeated measures on the last factor for Day 1 and a 3 × 3 design on Day 2. The first independent variable was type of practice, using groups that differ in speed and amount of practice (variable, specific, or control). Thirty participants matched for sex were randomly assigned to three groups of 10 subjects. The Variable Practice group received variable practice and performed 30 trials of 10 sec. duration on the pursuit rotor on two separate days. On Day 1, they practiced an equal number of trials at each of three different speeds (60, 45, and 30 rpm) randomly distributed over the 30 total trials. On Day 2, the Variable Practice group performed 15 trials of the pursuit rotor at the retention speed of 45 rpm and then 15 trials at the transfer speed of 75 rpm. The Specific Practice group performed 30 trials of 10 sec. duration on the pursuit rotor at 45 rpm on Day 1. On Day 2 they performed 15 trials at the retention speed of 45 rpm, then 15 trials at the 75 rpm transfer speed. The Control group only performed on Day 2, 15 trials at the 45 rpm speed then 15 trials at the 75 rpm transfer speed.

The second independent variable was blocks of trials. For Day 1 analysis, the trials were divided into three blocks of 10 trials. For Day 2, the 15 trials were divided into three blocks of five trials for both the 45-rpm retention speed and 75-rpm transfer speed. Two days separated the Day 1 and Day 2 testing sessions. Mean time on target for each block was used as datum.

Apparatus

The apparatus used was the Lafayette Photoelectric Rotary Pursuit (Lafayette Instruments, Lafayette, IN, Model No. 30014). The goal of the task was to keep a rigid L-shaped stylus on top of a 20-mm light spot rotating clockwise in a circular trajectory at the various speeds. Setting a variable speed motor controlled speed. Each trial was 10 sec. in length with a 10-sec. rest between trials. A Lafayette .01-sec. stop clock (Lafayette Instruments, Lafayette, IN, Model No. 54030) registered time on target.

Procedure

The motor task was administered to all subjects by the same male examiner in a nondistracting environment. Each subject was tested at approximately the same time of day. The task was explained and demonstrated by the examiner after which a 10-sec. trial was allowed to familiarize the subject with the task. A participant stood in front of the turntable with the stylus in the dominant hand, which each participant identified as the hand preferred for throwing an object. Time between applications of the stylus and a subsequent loss of contact was defined as time on target and was measured to the nearest .01 sec. Total time on target for each trial served as the index of performance.

Results

Tables 1 and 2 contain time on target means and standard deviations across blocks of trials for Days 1 and 2. The mixed model analysis of variance for time on target scores for Day 1 showed significant main effects for the Group variable ($F_{2,36} = 6.38$, $p = .02$) with the Specific group having the highest mean ($p \leq .05$). Significant main effects were also found for the Blocks of Trials variable ($F_{2,36} = 18.96$, $p < .001$) showing improvement with practice. Day 2 results showed significant retention (45 rpm) scores for the Group ($F_{2,27} = 22.64$, $p = .001$) main effect. Scheffé *post hoc* tests showed the Specific group having a significantly higher mean ($p \leq .05$) than the Variable and Control groups and the Variable group having a significantly higher

TABLE 1

Means and Standard Deviations For Time on Target Across Blocks of Three 10-sec. Trials For Practice Conditions, Retention and Transfer on Day 1

Block	Group	Time on Target	
		M	*SD*
1	Variable	1.81	.46
	Specific	2.49	.92
2	Variable	2.03	.39
	Specific	2.89	.98
3	Variable	2.27	.46
	Specific	4.03	.66

TABLE 2

Means and Standard Deviations For Time on Target Across Blocks of Three 10-sec. Trials For Three Practice Conditions, Retention and Transfer on Day 2

Block	Group	Retention		Transfer	
		M	*SD*	*M*	*SD*
1	Variable	2.91	.78	1.06	.32
	Specific	3.98	.69	1.23	.31
	Control	1.54	.67	.80	.48
2	Variable	3.14	.75	1.33	.33
	Specific	4.22	.68	1.53	.45
	Control	2.07	.91	.83	.39
3	Variable	3.15	.75	1.91	.21
	Specific	4.03	.66	1.55	.40
	Control	2.21	.89	1.24	.50

mean ($p \leq .05$) than the Control group. For Day 2 transfer (75 rpm) scores, a significant Group by Blocks of Trials interaction ($F_{4,54} = 6.88$, $p = .001$) was found. The interaction was ordinal in nature caused by a significant difference between groups on trial Block 3, on which the Variable group had a significantly higher mean than the Specific and Control groups and the Specific group had a significantly higher mean than the Control group (Scheffé, $p \leq .05$).

Discussion

Day 1 analysis showed significant differences between the Blocks of Trials indicating that participants improved with practice. The analysis also showed the Specific group performed better on the pursuit rotor than the Variable Practice group on Day 1. It should not be surprising that the Specific group produced higher scores with practice on Day 1 acquisition trials because they were practicing the same movement compared to the Variable group which practiced different variations (speeds) of the same continuous task. This type of specific practice is consistent with the concept of task specificity which supports specific actions for specific target contexts (Lordahl & Archer, 1958; Namikas & Archer, 1960; Schmidt & Wrisberg, 2000).

The Day 2 analysis indicates variable practice was more conducive to transfer to a novel speed, while specific practice was more conducive to retention of the specific skill (45 rpm) practiced. These results differ from those of Shea and Kohl (1990) who investigated the task specificity and variability of practice hypotheses to assess efficacy on retention and transfer of a discrete motor skill. They found that practice on a force-production task with variations in the amount of force led to better retention and transfer than specific practice on the criterion task alone. The present study differed from the Shea and Kohl study in that a continuous motor skill was used as the criterion variable as opposed to a discrete motor skill.

Discrete motor skills are hypothesized to be performed more open looped with movement production relying on a generalizable motor program that is carried out without the use of feedback. Practice results in rule formation, which becomes abstracted and stored for a class of movements in the form of a generalizable motor program (Schmidt, 2003). Variable practice is considered more conducive to learning under this theory.

Continuous skills are hypothesized to use a more closed-loop means of motor control, using feedback to monitor the movements while they are being performed. Feedback is assumed to help develop a memory trace for that particular skill, which results in better retention (Adams, 1971; Stelmach, 1982). Our results support the assumption of specificity and closed-loop motor control leading to better retention. However, for transfer, our results support the variability of practice position. While the difference in the transfer speed was not seen until the third trial block, it was assumed that this was caused by the short-term negative transfer from previous practice trials at the 45 rpm criterion speed. A few attempts were required to adapt to the transfer speed which would also explain the statistical interaction.

One of the assumptions of the present study was that the rotary pursuit was performed in a closed-loop fashion because the speed was slow enough that participants could take in and utilize the feedback during the movement. This may be incorrect. At faster speeds, the subjects may have been forced to switch to a more open-loop means of motor control where, instead of making continuous patterns of movement, they reverted to making shorter discrete hits of the target. This might account for the Specific Practice group scoring higher on the retention task and the Variable Practice group scoring higher on the transfer task. The retention speed of 45 rpm may have been slow enough that the closed-loop feedback strategy could be utilized, while at the faster speeds the open-loop strategy was adopted.

These results suggest that, when teaching a continuous, quasi-continuous or serial motor skill, the target context in which the skill will be performed may identify the most efficient type of practice. Instructors preparing students to perform continuous motor tasks in stable environments where the skills are self-paced and consistency of movement is important, e.g., rowing a boat, swimming, or maintaining a posture in gymnastics, should practice as close to the real-life situation as possible. Variable practice, on the other hand, might be employed when the purpose is to develop a more flexible movement pattern that would be performed in environmental conditions which constantly change. For example, when teaching the dribbling of a basketball or soccer ball for which game situations require constant changes in speed and direction of movement, variable practice might be more conducive to learning. Researchers need to examine other research designs that further delineate the role of factors such as proximity of retention and transfer speeds to those practiced during acquisition and various combinations of variable practice and specific practice speeds.

REFERENCES

ADAMS, J. A. (1971) A closed-loop theory of motor learning. *Journal of Motor Behavior*, 3, 111-150.

ADAMS, J. A. (1987) Historical review and appraisal of research on learning, retention, and transfer of human motor skills. *Psychological Bulletin*, 101, 41-47.

BRADY, F. (1997) Contextual interference and teaching golf skills. *Perceptual and Motor Skills*, 84, 347-350.

CHRISTANA, R. W., LAMBERT, P. J., & FISCHMAN, M. G. (1982) Hand position as a variable determining the accuracy of aiming movements. *Journal of Experimental Psychology: Human Perception and Performance*, 8, 341-348.

COULL, J., TREMBLAY, L., & ELLIOTT, D. (2001) Examining the specificity of practice hypothesis: is learning modality specific. *Research Quarterly for Exercise and Sport*, 72, 345-355.

FRENCH, K. E., RINK, J. E., & WERNER, P. H. (1990) Effects of contextual interference on the retention of three volleyball skills. *Perceptual and Motor Skills*, 71, 179-314.

GOODE, S., & MAGILL, R. A. (1986) Contextual interference on retention of three badminton serves. *Research Quarterly for Exercise and Sport*, 4, 308-314.

HAMMERTON, M. (1989) Tracking. In D. H. Holding (Ed.), *Human skills*. (2nd ed.) Chichester, Eng.: Wiley. Pp. 171-195.

HENRY, F. M. (1960) Increased response latency for complicated movements and a "memory drum" theory of neuromotor reaction. *Research Quarterly*, 31, 448-458.

JARUS, T., WUGHALTER, E. H., & GIANUTSOS, J. G. (1997) Effects of contextual interference and conditions of movement task on acquisition, retention, and transfer of motor skills by women. *Perceptual and Motor Skills*, 84, 179-193.

LORDAHL, D. S., & ARCHER, E. J. (1958) Transfer effects on a rotary pursuit task as a function of first task difficulty. *Journal of Experimental Psychology*, 56, 421-426.

NAMIKAS, G., & ARCHER, E. J. (1960) Motor skill transfer as a function of intertask interval and pretask task difficulty. *Journal of Experimental Psychology*, 59, 109-112.

PROTEAU, L., & CARNAHAN, H. (2001) What causes specificity of practice in a manual aiming movement: vision dominance or transformation errors? *Journal of Motor Behavior*, 33, 226-235.

PROTEAU, L., TREMBLAY, L., & DEJAEGER, D. (1998) Practice does not diminish the role of visual information in on-line control of a precision walking task: support for the specificity of practice hypothesis. *Journal of Motor Behavior*, 30, 143-151.

SCHMIDT, R. A. (2003) Motor schema theory after 27 years: reflections and implications for a new theory. *Research Quarterly for Exercise and Sport*, 74, 366-376.

SCHMIDT, R. A., & WRISBERG, C. A. (2000) *Motor learning and performance: a problem based approach*. Champaign, IL: Human Kinetics.

SHEA, C. H., & KOHL, R. M. (1990) Specificity and variability of practice. *Research Quarterly for Exercise and Sport*, 62, 169-177.

SHERWOOD, D. E., & LEE, T. D. (2003) Schema theory: critical review and implications for the role of cognition in a new theory of motor learning. *Research Quarterly for Exercise and Sport*, 74, 376-383.

STELMACH, G. E. (1973) Feedback: a determiner of forgetting in short-term memory. *Acta Psychologica*, 37, 333-339.

STELMACH, G. E. (1982) Motor control and motor learning: the closed-loop perspective. In J. A. Scott Kelso (Ed.), *Human motor behavior: an introduction*. Hillsdale, NJ: Erlbaum. Pp. 93-111.

Accepted May 31, 2005.