VARIABLE PRACTICE VERSUS CONSTANT PRACTICE IN THE ACQUISITION OF WHEELCHAIR PROPULSIVE SPEEDS

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Summary.—Previous studies have demonstrated that varied practice (involving several versions of a skill) has advantage over constant practice (involving only one version of a skill) in learning a motor skill. However, the support for variable practice mainly came from studies using discrete motor skills. Therefore, the purpose of the study was to assess if variable practice was more effective than constant practice for the purpose of learning a continuous and real-life motor skill: wheelchair propulsion. A total of 36 able-bodied undergraduate students participated in this study. There were two constant-practice groups. One group practiced wheelchair propulsion on a roller system with a single speed, 30% of the maximum speed (30%-only group), and one group practiced using 55% of the maximum speed (55%-only group). One variable-practice group (variable group) practiced the propulsion with two different speeds, 30 and 55% of the maximum speed. In addition to retention tests, two transfer tests (i.e., tests on 40 and 70% of the maximum speeds) were performed by the three groups after the 10 weeks of training. The results were mixed. The variable-practice group produced significantly fewer absolute errors on both transfer tests than the 30%-only group. However, when compared to the 55%-only group, the variable-practice group only produced significantly fewer absolute errors on the transfer test at 70% speed, but not at 40% speed.

The schema theory (Schmidt, 1975) predicts the advantage of variable practice (involving several versions of a skill) over constant practice (involving only one version of a skill) in learning a motor skill. This is because variable practice can effectively strengthen the recall schema, the relationship between movement outcomes and parameters assigned to produce them, and the recognition schema, the relationship between movement outcomes and the sensory consequences produced for various initial conditions. Support for the superior effect of variable practice over constant practice mainly came from studies involving ballistic discrete skills, and these effects were demonstrated in both transfer and retention tests (McCracken & Stelmach, 1977; Shea & Kohl, 1990, 1991; Schmidt, 2003; Schmidt & Lee, 2005, p. 338-342). However, in a study involving learning a more real-life task (i.e., basketball free throw), Shoenfelt, Snyder, Maue, McDowell, and Woolard (2002) did not find significant difference in retention tests between the constant and variable practice groups.

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Shoenfelt, et al.’s study (2002) raises a question about whether the advantage of variable practice over constant practice in retention tests is limited only to well-controlled laboratory tasks.

It should be noted that the schema theory was originally developed for ballistic discrete skills only. Therefore, it is questionable whether or not the effect of variable practice found in studying ballistic discrete skills can be generalized to studying continuous skills. To answer this question, Heitman, Pugh, Kovaleski, Norell, and Vicory (2005) examined the effect of variable practice on learning a continuous skill (i.e., pursuit rotor). In this study (Heitman, et al., 2005), subjects were randomly assigned into one of three practice groups: the variable group, the specific group, or the control group. On Day 1, the variable group practiced three different speeds (i.e., 60, 45, 30 rpm) while the specific group practiced at 45 rpm only. The two groups had an equal number of practice trials. On Day 2, the two groups performed 15 trials on a 45-rpm retention test and 15 trials on a 75-rpm transfer test. The control group only performed on Day 2. Although Heitman, et al. found that the variable-practice group performed better only on the transfer test, the results of their study (Heitman, et al., 2005) tentatively indicate that variable practice may also benefit learning a continuous motor skill.

Wheelchair propulsion is also a continuous skill. However, it differs from pursuit rotor tasks in that subjects cannot apply visual feedback to guide their movement. Therefore, the purpose of this study was to assess if the results of variable practice in learning wheelchair propulsion would be the same as those found for learning a pursuit rotor skill.

**Method**

**Participants**

A total of 36 able-bodied undergraduate students (18 men, 18 women; age range = 20 to 41 years) who had never had any experience with using a wheelchair participated in this study. They were paid for their participation in the study.

**Apparatus**

A system consisting of a roller and a Quickie manual wheelchair (Quickie GPV: weight, 24.5 lbs; caster wheels, 3 in.; rear wheels, 22 in.; tire pressure, 3.005 Pa) equipped with a computerized speedometer was used to test and train all the subjects. The speed was recorded as kilometer/hour (km/hr.), and the experimenter provided verbal feedback to subjects whenever the actual speed was out of the acceptable speed window (e.g., beyond target speed ± 0.5 km/hr.). The feedback was qualitative, e.g., “too fast” if the actual speed was greater than the target speed + 0.5 km/hr., or
“too slow” if it was less than the target speed – 0.5 km/hr., or “good” if it was within the window of the target speed ± 0.5 km/hr.

Experimental Design

There were two constant-practice groups: one group practiced wheelchair propulsion at a single speed, 30% of the participant’s maximum speed (30%-only group), and one group practiced at 55% maximum speed (55%-only group). One variable-practice group (variable group) practiced the propulsion at two different speeds, 30 and 55% of maximum speed. The participants were assigned to one of the three groups randomly (12 participants in each of the three groups).

Training Phase

The study consisted of two phases: a training phase and a testing phase. Before the training phase started, the experimenter explained propulsive skills such as smoothly applying force to the wheel and matching the speed of the wheel with the hands, and then gave the subjects a physical demonstration of those skills. The subjects were also asked to maintain relatively smooth and constant stroke frequency throughout the propulsion period. Then, after 3 min. practice, subjects were asked to push the wheelchair as fast as possible, to measure each subject’s maximum propulsive speed. The training phase lasted 10 wk., with the subjects training three times a week. Each training period was split into six blocks. Each block was 5 min. long. There was a 3-min. break between any two pushing blocks. Again, the two constant groups practiced at only one of the two propulsive speeds. The variable group, on the other hand, had the same number of practices as the constant groups (i.e., three times per week), but the practices were varied, in that both propulsion speeds were practiced on each practice day (15 min. each).

During the practice, verbal feedback was provided by an experimenter whenever the propulsive speed was beyond ±0.1 km/hr. of the designated speed. As expected, all the participants across the practice conditions could maintain the target range (target speed ±0.1 km/hr.) during the practice. Because of the guidance of the verbal feedback, all practice conditions produced very small absolute errors (AE, the absolute value of the subtraction of target speed from the actual speed) during the practice phase. Therefore, the AE scores during practice phase were not recorded for the further analysis.

Testing Phase

The testing phase consisted of a pretest and a posttest. The pretest was conducted 10 min. after the maximum speed was determined for each participant, but before the training phase started. The participants in the pretest were asked to estimate 30, 40, 55, and 70% of their
maximum speed and to maintain the targeted speed for 5 min. Among the four testing speeds, 40 and 70% speeds were novel speeds (transfer tests) to all three groups. Each participant was randomly assigned into one of the four performance orders: (1) 40% → 30% → 55% → 70% speed, (2) 40% → 55% → 30% → 70% speed, (3) 70% → 30% → 55% → 40% speed, and (4) 70% → 55% → 30% → 40% speed. The posttest was conducted 3 days after the practice phase ended. During the test, all participants performed one block of 5 min. continuous pushing motion on each of the four propulsive speeds: 30, 40, 55, and 70% of maximum speed. Same as the pretest, participants in the posttest were randomly assigned into one of the four performance orders. No feedback was provided during the tests.

**Results**

The maximum pushing speed was tested before the training phase started and was analyzed with a one-way analysis of variance (ANOVA). The main effect was not significant \( F_{2,35} = 1.64, p > .20; M = 12.5 \text{ km/hr.}, SE = 0.55 \) for 30%-only group; \( M = 13.21 \text{ km/hr.}, SE = 0.61 \) for 55%-only group; and \( M = 14.29 \text{ km/hr.}, SE = 0.92 \) for variable group). The AE scores for the pretest and posttest were presented in Table 1 and were analyzed in \( 2 \times 4 \times 3 \) (test phases \( \times \) speed \( \times \) training group), with repeated measures on the first two factors. The main effect for test phases, as expected, was significant \( F_{1,33} = 190.19, p < .001 \). No other main effects were significant. However, the interactive effect between the speed and training group was significant \( F_{6,99} = 2.43, p < .05 \).

**TABLE 1**

**Mean Absolute Error (MAE, km/hr.) and Standard Error (SE) For Wheelchair Use at Various Percentages of Maximum Speed**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest Speed</th>
<th>Posttest Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30% 40% 55% 70%</td>
<td>30% 40% 55% 70%</td>
</tr>
<tr>
<td>30%-only</td>
<td>MAE</td>
<td>1.73 1.67 1.71 1.61</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.11 0.13 0.15 0.12</td>
</tr>
<tr>
<td>55%-only</td>
<td>MAE</td>
<td>1.61 1.67 1.52 1.68</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.19 0.18 0.19 0.12</td>
</tr>
<tr>
<td>Variable</td>
<td>MAE</td>
<td>1.69 1.74 1.79 1.62</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>0.13 0.10 0.11 0.16</td>
</tr>
</tbody>
</table>

For the pretest AE scores, the follow-up \( 4 \times 3 \) (speed \( \times \) training group) ANOVA with repeated measure on the first factor, as expected, no significant main and interactive effects were revealed. However, for the posttest AE scores, the \( 4 \times 3 \) (speed \( \times \) training group) ANOVA showed significant main effects on both speed factor and training group factor \( F_{3,99} = 4.10\),
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$p < .01$ and $F_{2,3} = 4.22$, $p < .05$, respectively). In addition, the interaction between the two factors (speed $\times$ training group) was also significant ($F_{6,99} = 5.34$, $p < .001$). The independent-sample $t$ tests were further conducted for the two novel speed tests, namely 40 and 70% speed tests. The $t$ tests indicated that the variable group produced significantly lower AE scores than the 30%-only group at both novel-speed tests, and than the 55%-only group at 70% speed test only. No other pair comparisons for the novel speed tests (i.e., 40 and 70%) were significant.

**Discussion**

As expected, all groups significantly improved their accuracy in performing the learned wheelchair propulsive speeds after the 10-wk. practice. The interesting finding, however, is that all groups also significantly improved their accuracy on novel speeds (i.e., 40 and 70%), which were not practiced by any of the groups. This finding could be explained by the Generalized Motor Program Theory proposed by Schmidt (Schmidt, 1975; Schmidt & Lee, 2005). Although the theory was originally developed for discrete skills only (Schmidt, 1975), it is possible that the theory is also applicable to a continuous motor skill as long as the skill is controlled with an open-loop system in which feedback is either not available or cannot be used to guide the movements while they are being performed. The wheelchair propulsive skill learned in the current study is a continuous motor skill. However, feedback such as vision cannot be used to monitor the movements while they are being performed. Therefore, the wheelchair propulsive skill might be controlled more by an open-loop system and governed by a generalized motor program.

According to the theory, the four propulsive speeds tested in the study might be governed by a single generalized motor program. After 10 wk. of practice, all training groups might have learned the program. Therefore, their posttests, after learning the program, were all better than their pretests. These results are consistent with the study by Shoenfelt, et al. (2002), in which all of their practice groups significantly improved the shooting rate of basketball free throws after 3 wk. of practice.

The main focus for this study was on examining which group, constant versus variable, could generalize the learned program into performing a novel version, or versions, of the learned skill better. The schema theory (Schmidt, 1975) predicts the superior performance of varied practice over constant practice in learning a motor skill. The theory was supported by the current study. Of the four testing speeds, only 40 and 70% of the maximum speed were novel to every group. When compared to the 30%-only group (one of the two constant practice groups), the variable group produced significantly lower AE scores on the two novel speed tests (transfer tests). However, when comparing the variable group to the
55%-only group, the results were mixed. There was no significant difference between the two groups on the transfer test at 40% speed, which was in the range of experience for the variable group (i.e., from 30 to 55% speed). On the other hand, the variable group performed significantly better than the 55%-only group on the transfer test of 70% speed, which was outside the previous experience for both groups. These mixed results were assumed to be caused by the interactive effects of practice adaptation and practice variability. That is, the effect of practice variability, when comparing the variable group to the 55%-only group, might be limited to a transfer test beyond the range of previous experience only. It was, however, shadowed by the effect of practice adaptation when a transfer test was in the range of previous experience.

According to the Generalized Motor Program Theory, motor skill learning includes both program learning and parameter learning (Schmidt, 1975; Yao, 2003; Schmidt & Lee, 2005). Program learning consists of learning the fundamental pattern of the class of actions. Parameter learning, on the other hand, includes training effectors such as involved muscles. Pushing speed is decided by resultant muscle strength generated by involved muscles. Muscle strength is mainly regulated by two characteristics of motor-unit behaviors, namely, motor-unit recruitments and motor-unit discharge rate (Yao, Enoka, & Fuglevand, 2000; Yao, 2003). According to the size principle of motor-unit recruitment (Heckman & Binder, 1990), when pushing the wheels at the 55% speeds during the training phase, the motor units recruited would include two categories of motor units, those that were recruited earlier when pushing at lower speeds and those larger-size motor units which were just newly recruited. In other words, the motor units responsible for pushing the wheels at lower speeds were trained to some extent when they were recruited for pushing the wheels at faster speeds. Although the 55%-only group might have not learned the schema (program) as well as the variable group, when they performed a transfer test within the range of previous speeds, this shortcoming was overcome by the appropriate parameter learning (i.e., well-trained muscle parameters).

Overall, the current study is one of the few to provide evidence to suggest that variable practice strategy may benefit the learning of continuous motor skills. In this study, it is assumed that there might be an interactive effect between practice adaptation and practice variability. However, due to the limitation of the current study, this assumption could not be examined. This assumption is expected to be examined in a future study.
REFERENCES


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