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Limited generalization with varied, as compared to specific, practice in short-term motor learning

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ABSTRACT

The schema theory of learning predicts that varied training in motor learning should give rise to better transfer than specific training. For example, throwing beanbags during practice to targets 5 and 9 ft away should better generalize to targets 7 and 11 ft away, as compared to only throwing to a target 7 ft away. In this study, we tested this prediction in a throwing task, when the pretest, practice, and posttest were all completed within an hour. Participants in the varied group practiced throwing at 5 and 9 ft targets, while participants in the specific group practiced throwing at 7 ft only. All participants reliably reduced errors from pretest to posttest. The varied group never outperformed the specific group at the 7 ft target (the trained target for the specific group). They did not reliably outperform the specific group at 11 ft, either. The numerically better performance at 11 ft by the varied group was due, as it turned out in a subsequent experiment, to the fact that 11 ft was closer to 9 ft (one of the two training targets for the varied group) than to 7 ft (the training target for the specific group). We conclude that varied training played a very limited role in short-term motor learning.

1. Introduction

Implicit learning in general relies on incremental improvements over time through feedback and practice. Motor learning research has focused on understanding the mechanisms in which new motor skills are acquired across different learning scenarios (for reviews, see Shapiro & Schmidt, 1982; Schmidt & Bjork, 1992). One of the leading theories, the schema theory, suggests that motor skills are learned through the development of motor schemas that can be generalized to other similar scenarios.

Using the schema theory as a foundation, much of this literature details ways in which motor learning can be optimized. One idea in the general schema theory literature that has recently received increased attention is that variability introduced during practice can improve later performance (Boutin & Blandin, 2010; Breslin, Hodges, Kennedy, Hanlon, & Williams, 2010; Breslin, Hodges, Steenson, & Williams, 2012; Feghhi, Abdoli, & Valizadeh, 2011; Jones & Croot, 2016). The schema theory suggests that practicing different but similar tasks during the same training session should improve learning and long-term retention. For example, a trainee could alternate between shooting a basketball from the free throw line and the three-point line, controlling for shooting angle. While shooting from the three-point line may be more difficult because of the increased distance, the trainee can utilize the same movement plan used at the free-throw line while using a different force. This type of practice, in theory, allows for the trainee to develop a generalized motor program over time that includes a range of forces that are applicable to both the trained target distances and untrained distances (Adams, 1971; Schmidt, 1975). One can contrast between a session that practices shooting to two distances (varied practice) to a session that focuses on shooting to just one distance (specific practice) using the same number of throws. Based on the schema theory, trainees in a varied practice condition should generalize not only to distances located between the two practiced distances (e.g., between the three-point and free-throw lines), but also to a range outside of the practiced distances (e.g., farther than the three-point line or closer than the free-throw line), better than a specific practice group that practiced at only one distance. Predictions based on the schema theory are in contrast with theories in other implicit types of learning. Particularly, in perceptual learning, learning is found to be very specific to the trained conditions (Fahle, 2005; Fahle & Poggio, 2002; Gibson, 1969; Sagi, 2011). Specificity in learning would predict that groups have limited generalization to untrained distances regardless of the practice scheme.

Kerr and Booth (1978) were among the first to empirically test the hypothesis that a varied type of practice would result in better generalization than a specific type of practice. In their experiment, grade-school student participants in the specific group practiced throwing to one target distance (e.g., 4 ft away) and those in the varied group practiced throwing to two target distances (e.g., 3 ft and 5 ft away)

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within the same number of practice trials. Kerr and Booth (1978) found that, after long-term physical education training at the students' school, the varied group performed better than the specific group at the exact distance that the specific group had practiced at. These advantages of varied practice have mostly been described to occur only after a long-retention period. Research on variability in short-term retention after a single practice session has mixed findings. Some researchers were unable to find advantages of varied practice in the short term (Feghhi et al., 2011; Schmidt, 1975; Schmidt & Bjork, 1992); some have found disadvantages (Shea & Morgan, 1979); while others have found benefits after short-term retention and practice (Gabriele, Hall, & Buckolz, 1987).

Beyond varied and specific training, however, there has been some research to investigate varying sources of variability on short-term performance. The current study seeks to use Kerr and Booth's (1978) paradigm to investigate the extent to which variability from different sources can influence short-term performance at trained and untrained target distances in a simple motor learning task. There are many potential sources of variability that may influence how generalization manifests after varied and specific training schedules. In the following experiments, we investigated how variability affects motor learning acquisition in a novel throwing task with adult participants. The first goal of the study was to investigate whether there was an advantage of varied training after a short retention period in a throwing-for-accuracy task. Specifically, in the first two experiments, we explored whether varied or specific training could be responsible for generalization away from the trained distance(s). We then investigated the effect of variability from different sources, which were either directly or indirectly related to the task. Specifically, we looked at the effects of variability added as a result of giving a pretest and an increase in contextual interference introduced by switching hand throughout practice. Further, we investigated how knowledge of results may influence transfer performance. In general, the schema theory would predict that when variability is decreased within the methodological procedures one would see a decrease in generalizability to untrained distances, particularly within the specific practice group.

2. Experiment 1: Specific (7 ft) and varied (5 and 9 ft) training groups tested from 3 to 11 ft

2.1. Method

We recruited 60 participants from the UCLA human participant pool. All participants had normal or corrected-to-normal vision and two participants were left-handed. They threw a 9.05 oz. beanbag to various distances during a pretest, two practice blocks, and a posttest. During all throws, the participant threw the beanbag over their shoulder, with their back facing the targets, in order for the task to be sufficiently difficult. All target distances were marked on the ground from the participant's standing position. The targets ranged from 3 to 11 ft in two-foot increments (total of 5 distances). After each trial, a trained research assistant recorded the thrown distance by measuring the shortest distance from the beanbag to the nearest target line.

2.1.1. Pretest

During pretest, participants threw 12 beanbags (one at a time) to each of the five distances in a blocked design. The order of the five blocks was random. For each distance, participants only viewed once the distance that they aimed for at the beginning of the 12 trials and were given no visual or verbal feedback between trials. The research assistant would indicate when the participant could make their next throw. All throws were made with the participant's non-dominant hand. We chose to test the non-dominant hand to increase the general difficulty.

2.1.2. Practice blocks

Participants were randomly assigned to one of the two practice groups. During practice, the specific group ($N = 30$) aimed their throws for a target 7 ft away, while the varied group ($N = 30$) alternated (every 12 trials) between targets 5 ft and 9 ft away. Both groups completed 60 throws in each of the two practice blocks. Unlike in the pretest, participants were instructed to turn their head to view the result of each throw and were given explicit verbal feedback about the distance of each throw. After each practice block, participants took a five-minute break before continuing. Participants also switched between their hands every six trials in order to reduce fatigue of the tested hand and to retain their attention and interest. We explored how using only one hand throughout the entire experiment affected performance in the varied and specific groups in Experiment 4.

2.1.3. Posttest

After the second 5-minute break, participants began the posttest, which was identical in procedure to the pretest except that the sequential order of the five blocks was reversed.

2.1.4. Analyses

In order to assess learning for each group, we conducted analyses on pretest and posttest data using each set of the 12 individual test trials at each target distance. For each individual test trial, we calculated the signed and unsigned errors by taking the signed or unsigned difference between the target and the landing position. A positive signed error indicated an overthrow to the target. Using these individual errors, we calculated per participant, a constant error, an absolute error, and a variable error to run the analyses. A constant error (CE) is the mean of the individual signed errors. An absolute error is the mean of the individual unsigned errors. A variable error (VE) is defined as follows:

$$\mathrm{VE} = \sqrt{\frac{\sum (\mathrm{CE} - \mathrm{M_{CE}})^2}{\mathrm{N}}},$$

where N = 12, the total number of throws per condition per participant.

Here we focus on analyses using CE and VE, but will mention any notable findings in absolute error in Experiment 1 since Kerr and Booth (1978) found their primary effects between groups using absolute errors. The reason for focusing on CE and VE throughout is because it has been argued that absolute error is a combination of both CE and VE and therefore the CE and VE are all that is needed to understand the nature of the errors made (Schultz & Roy, 1973).

Our predictions were as follows. Errors were expected to decrease from pretest to posttest, if learning had occurred. Since longer distances are naturally more difficult, according to Weber's Law, errors were also expected to increase as the distance increases. Additionally, the varied group was expected to reduce errors more than the specific group, according to the schema theory.

2.2. Results

We first checked for any between-group differences in the pretest in CE. A 2(Group) × 5(Distance) ANOVA was conducted within pretest, and no group differences were found, as expected, $F\ (1, 58) = 0.001$, $p = 0.98$. There was no interaction between target distance and group either, $F\ (4, 232) = 0.98$, $p = 0.42$. As a result, we plotted the pretest performance in Fig. 1 by combining both groups together. A similar null group effect was found for VE, $F\ (1, 58) = 0.44$, $p = 0.509$.

Next, we compared CE between pretest and posttest, and conducted a 2(Group) × 2(Time) × 5(Distance) mixed ANOVA. We found the expected main effect of time, $F\ (1, 58) = 14.97$, $p < 0.001$, $\eta_p^2 = 0.21$, indicating learning. We also found that errors followed a significant negative linear trend across distances, $F\ (1,58) = 53.37$, $p < 0.001$, $\eta_p^2 = 0.48$, indicating the effect of Weber's Law since the