Future Research on Practice-Distribution Effects

You may have noticed that since the 1940s and 1950s when much of the research on distribution-of-practice effects was conducted, with only a few exceptions, work on this issue has stopped. Why is this the case? One possibility is that everything we could know about the topic is now known. However, this is unlikely to be true; for example, the different effects for continuous versus discrete tasks have never been satisfactorily explained. Two reasons for this lack of work relate specifically to theory testing. One reason for the decline in research in this area is that topics in learning with more exciting theoretical appeal have attracted the researchers' attention. The other reason relates to the downfall of Hull's theory (Ammons, 1947; Hull, 1943), which stimulated much of the early work in this area: Hull's theory was never replaced by another formulation that would serve as an impetus for further research (Adams, 1987; Ammons, 1988; Magill, 1988b; Newell, Antoniou, & Carlton, 1988).

It is clear that practice-distribution effects have important implications for the design of training sessions for learning motor skills. However, the applied nature of this work seems to be insufficient to drive sustained research in this area. Only when (and if) theory development resumes on this issue, it seems, will new experiments be designed and carried out.

Variability of Practice

Another factor that has been shown to affect learning is the amount of variability in a practice sequence. In one sense, this is obvious. Many tasks have variability inherent to them *(open skills)*, such as fielding ground balls in baseball or steering a car down an unfamiliar road. An important part of learning such tasks is acquiring the capability to cope with novel situations; practicing under constant (unvarying) situations would probably not be appropriate. But in another sense, this effect is not so obvious, especially when the task involves *closed skills*, for which the environmental conditions are always quite similar (e.g., archery, bowling). Here, because the criterion task to be learned is always the same, it would seem that practice under these exact conditions would be most effective for learning. Yet the evidence suggests that varied practice may be important in closed tasks as well.

Much of the research on variability of practice has been conducted to test certain predictions of *schema theory* (Schmidt, 1975b). One prediction was that transfer to novel tasks would be enhanced after practice in variable, as compared to constant, practice conditions (see chapter 13 for more on schema theory). We discuss only a few of these studies; reviews of many more of these experiments are available (Lee, Magill, & Weeks, 1985; Shapiro & Schmidt, 1982; Van Rossum, 1990).

Variability-of-Practice Effects in Retention

One way to obtain an indication of the effect of practice variability is to assess retention performance, after a period of time following the acquisition session, for one of the tasks that has been practiced. A few studies have done this by comparing the relative impacts of constant and varied practice on retention of the tasks that were practiced. There is a design complication with this type of study, however, as subjects in the different groups practice different tasks; thus what has been practiced and what is assessed in retention cannot be equated. This does not pose a problem, however, for results such as those we will see in studies conducted by Shea and Kohl (1990, 1991).

Subjects in the Shea and Kohl experiments were asked to learn to generate a goal force by squeezing a hand grip that was connected to a force transducer. In one experiment (Shea & Kohl, 1991, experiment 1), subjects performed 100 trials on the criterion task, which was to produce a force of 150 N. One group (criterion) received only these acquisition conditions. Another group (criterion + variable) received the same number of acquisition trials on the criterion task but, in addition, practiced goal forces that were ±25 or ±50 N relative to that of the criterion task (i.e., 100, 125, 175 and 200 N). Notice, however, that this variable-practice group not only had the same amount of specific practice as the criterion group, but also practiced at tasks that surrounded the criterion task—which confounds the role of the variable practice with additional practice. So, Shea and Kohl also included a third group of subjects (criterion + criterion) that practiced the criterion task, as well as performing additional practice trials on the criterion task, so that the total number of practice trials was equal to the total practiced by the variable group.

Performance on the criterion task for these groups in acquisition and in a retention test 1 day later is presented in figure 11.5. The criterion + variable practice group performed more poorly on the criterion task almost all the way through the acquisition period in comparison to the other two groups. This detrimental effect on performance is similar to the effects of random practice that we saw in the Shea and Morgan (1979) study discussed in chapter 10. However, after the retention interval, subjects in the criterion + variable practice group performed better on the retention test than both the criterion-only group and the criterion + criterion group. These findings indicate that practice at tasks that were similar to (and "surrounded") the criterion task, actually *facilitated* the retention of the criterion task.

Variability-of-Practice Effects in Transfer

In one of the first studies investigating transfer, McCracken and Stelmach (1977) had subjects move their right arms from a starting key to knock over a barrier, with a 200-ms goal MT from initiation to barrier contact. The distances to the barrier could be changed in different conditions (15, 35, 60, and 65 cm), with a constant 200-ms goal in the practice phase. Table 11.1 shows the two-group design. A Constant group was actually made up of four subgroups, each of which had practice at only one of the barrier distances for 300 trials. The Variable group, on the other hand, had the same number of trials as the Constant group (i.e., 300), but these trials were varied in that all four barrier distances were practiced in a random order (75 trials of each).

In a transfer-test phase, the two groups performed a *novel* (50-cm) distance, both immediately after training and after a 2-day interval. Thus, with this basic design the authors evaluated the effect of variable versus constant practice on the performance of a novel variation that had never been performed previously. This design addresses an effect of learning quite different from that studied in the retention design by Shea and Kohl (1991) discussed in the preceding section. In that study, Shea and Kohl assessed how well one *common* task, practiced by all the groups, was *retained* as a function of the other tasks that had also been practiced. In the McCracken and Stelmach study, the primary research interest was the effect of varied versus constant practice on the capability to perform a *new task*.

The results are shown in figure 11.6, where the absolute errors are plotted for the trials at the end of the acquisition phase, as well as for the trials on the two transfer-test phases. In the original-practice phase, the Constant group had less absolute error than the Variable group. This finding is

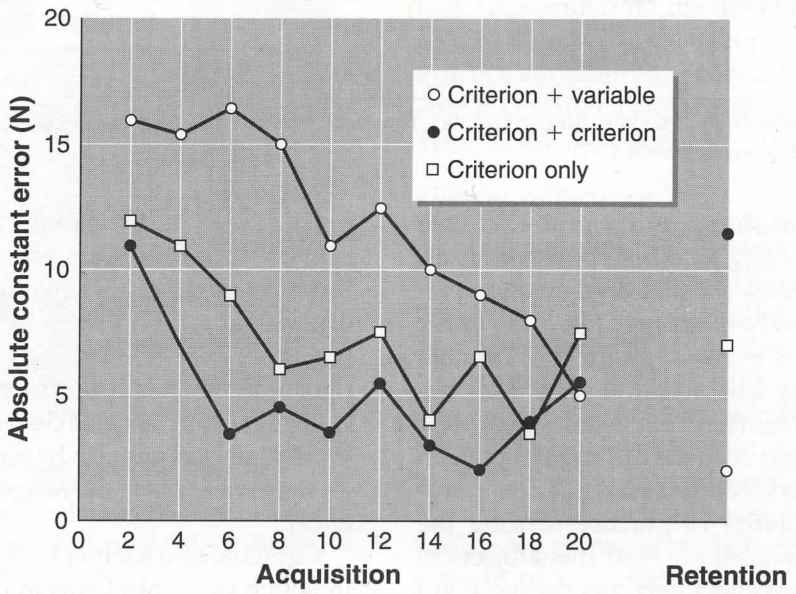

Figure 11.5. Comparison between variable-practice conditions and practice at the criterion task during acquisition and retention performance on the criterion task.
Adapted from Shea and Kohl, 1991.

Table 11.1 Experimental Design for an Experiment on Variability in Practice

Group	Original practice: 300 trials Day 1	Transfer-test phase: Immediate Day 1	Delayed Day 2
Constant			
Subgroup a	15 cm only	50 cm	50 cm
Subgroup b	35 cm only	50 cm	50 cm
Subgroup c	60 cm only	50 cm	50 cm
Subgroup d	65 cm only	50 cm	50 cm
Variable	15, 35, 60, 65 cm	50 cm	50 cm

(Adapted from McCracken and Stelmach 1977.)

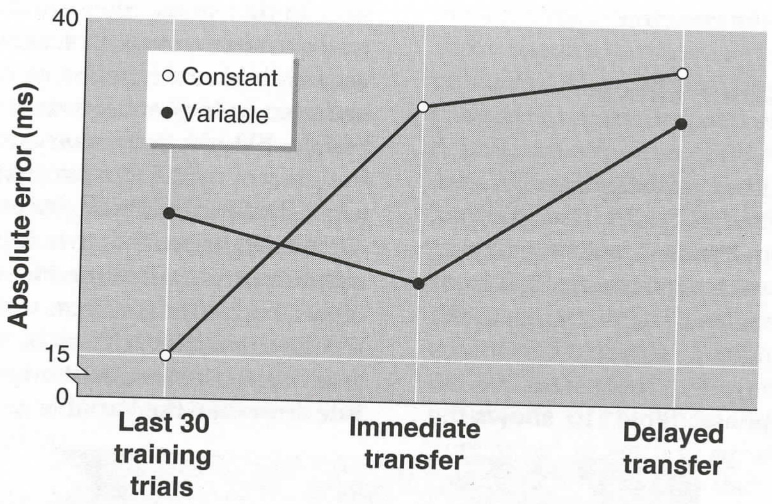

Figure 11.6. Performance in a ballistic timing task as a function of variability in practice conditions. Adapted from McCracken and Stelmach, 1977.

similar to the results shown by Shea and Kohl (see figure 11.5). The critical contrast, however, is on the immediate transfer-test phase, when the movement was novel for both groups. Here, the order of the groups was reversed, with the Variable group now having less absolute error than the Constant group. This trend persisted into the test phase 48 hr later, but with the difference between groups being considerably smaller. Thus, it appeared that variability in practice (during the original-practice phase) allowed the subjects to learn the task more effectively, permitting them to perform a new version of it on the transfer phase with less error than the Constant group (see also Wrisberg & Ragsdale, 1979). Variable practice seemed to be important in generating a capacity to perform a novel version of this task. But this novel task (50 cm) was clearly within the original range of experience of the Variable group (i.e., from 15 to 65 cm), and one could argue that the Variable group had more practice than the Constant group at tasks closer to the transfer task. Would such effects also be seen if the novel transfer task was *outside* the range of previous experience?

Catalano and Kleiner (1984) used a timing task in which the subject was to press a button when a moving pattern of lights arrived at a coincidence point. Using a design much like that of McCracken and Stelmach (1977), they had a mph; a Constant group (with four subgroups) practiced at only one of these speeds. Then, on a subsequent transfer test, all subjects transferred to four *novel* light speeds that were outside the range of previous experience (i.e., 1, 3, 13, and 15 mph). The performance of the two groups on these transfer tests is shown in figure 11.7. The absolute errors were smaller for the Variable group than for the Constant group, and the differences were present even when the "distance" from the range of previous experience was quite large. Variable practice appeared to increase the "applicability" of the learning that occurred in acquisition, contributing to the performance of novel variations of the task that were well outside the range of the stimuli experienced in the acquisition phase. In other words, variable practice seemed to increase *generalizability*, an important criterion for motor learning as discussed in chapter 10. Also, one cannot argue that the Variable group was more effective simply because it had experienced the range of speeds involved in the transfer test, as neither group had experienced them.

Other Factors Influencing Effects of Practice Variability

When adults are used as subjects, there is reasonably strong evidence that increased variability is

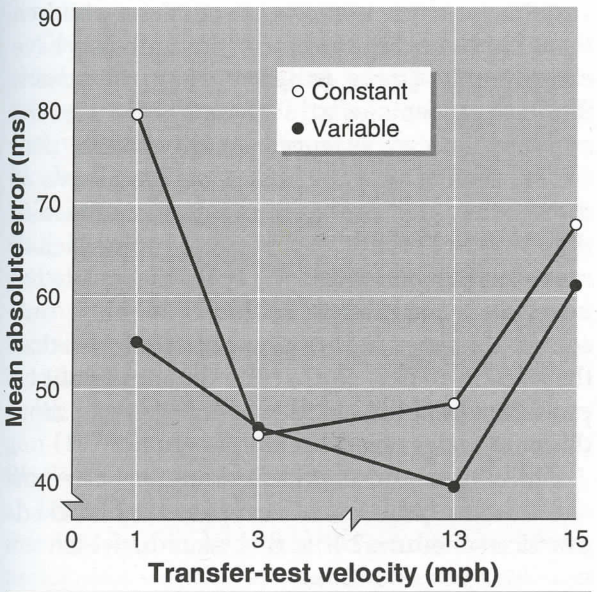

Figure 11.7. Mean absolute timing error for novel transfer of light speeds as a function of the variability in practice conditions in acquisition.
Adapted and reproduced with permission of authors and publisher from: Catalano, J.F., & Kleiner, B.M. Distant transfer in coincident timing as a function of variability of practice. *Perceptual and Motor Skills*, 1984, 58, 851-857. © Perceptual and Motor Skills 1984.

beneficial for learning (as measured on novel transfer tests), and basically no evidence that variable practice is detrimental to learning (Shapiro & Schmidt, 1982). However, a number of studies show very small effects, and others show essentially no effects, casting some doubt on the "strength" or generality of these effects (Van Rossum, 1990). Overall, in practical settings it is reasonably safe to say that attempts to make the practice more variable for learners will result in greater learning and generalizability. However, some of the issues that complicate this general statement are presented in the following paragraphs.

Age of Learner

The effects of practice variability seem to depend on the nature of the learners. Certainly the most obvious classification is that of children versus adults. In their review of the literature on practice variability, Shapiro and Schmidt (1982) noted that the advantage for variable versus constant practice for children was strong in nearly every study conducted. For example, using a strictly closed throwing skill with young children, Kerr and Booth (1977, 1978) found in two experiments that variable practice was more effective than constant practice when subjects were transferred to a novel version of the task. Even more surprising was the finding that for learning this novel variation of the task, practice at variations of the task approximating the novel task was more effective than was practicing the *novel task itself!* Practice variability appears to be a powerful variable in children's motor learning (see also Green, Whitehead, & Sugden, 1995; Wulf, 1991).

Gender of Learner

Another individual-difference variable of interest is gender. Wrisberg and Ragsdale (1979), with basically the same task as that used by Catalano and Kleiner (1984; see figure 11.7), found that college women profited from practice variability much more than college men did. In fact, it appeared that male subjects may not have profited at all, as all of the group differences were attributable to the women subjects. With children, as well, more gain was made by first-grade girls as a result of variability in practice than by first-grade boys (Allen, 1978). Thus, variability in practice tended to be more effective for females than for males, at least in these two studies.

Scheduling Variable Practice

We mentioned earlier that the effects of variable practice in adults have not always been consistent—some studies showing positive effects and others showing no effects (although none that we know of has shown negative effects). A review of those studies showing no effects by Lee, Magill, and Weeks (1985) revealed an interesting pattern of findings. Many of these experiments had structured the variable-practice sessions such that most or all of the practice on any single variant of the task was conducted together, in a *blocked-practice sequence.* Although we will have much more to say about the effects of random and blocked practice in the next section, the conclusion drawn by Lee, Magill, and Weeks (1985) was that for variable practice to be most effectively utilized (relative to constant practice) it should be randomized in order, rather than blocked.

Interpreting Variability-of-Practice Effects

Most of the studies on variability have been done in the context of schema theory (chapter 13). The basic premise is that, with practice, people develop rules (called *schemas*) about their own motor behavior. Think back to the ideas about the generalized motor program (chapter 6), indicating that a set of parameters must be applied to the program in order for it to be performed. Schema theory proposes that subjects learn a rule in the practice sequence. The rule is a relationship between all the past environmental outcomes that the person produced and the values of the parameters that were used to produce those outcomes. This rule is maintained in memory and can be used to select a new set of parameters for the next movement situation—even a novel variation—that involves the same motor program. Knowing the rule and what environmental outcome is to be produced, the person can select the parameters for the program that will produce it. The schema theory is related to variability in practice because the theory predicts that learning of the rule will be more effective if the experience is varied rather than constant. We will refer to these experiments on variability in practice in chapter 13 when we discuss schema theory in more detail.

Another important finding from the literature on variability in practice is that the occurrence of learning during the acquisition phase was revealed by performance on a *novel* version of the task in transfer. This was true regardless of whether the novel version was inside (McCracken & Stelmach, 1977) or outside (Catalano & Kleiner, 1984) the range of variation experienced in the acquisition phase. As we will point out in chapter 13, such evidence suggests that what was learned was *not* some particular movement, but rather the (generalizable) capability to produce any of a variety of movements of this type. These results are explained well by schema theory, in that the variable practice produces a rule (or schema) for selecting parameters of the generalized motor program (e.g., for throwing), and this rule can be used for any novel movement using the same motor program.

Why should variable practice be more effective for children and females? One idea is that children are less experienced at motor skills than are older (adult) subjects, so the rules (schemas) that the children acquire in laboratory settings have already been achieved by the adults in their earlier experiences with motor tasks. Also, the laboratory tasks are very simple, and it is possible that the adults already have at their disposal the rules (schemas) necessary to perform the novel tasks whereas the children must learn some of them in the experimental setting. Here, then, variable practice is more effective for children than for the adults because the children have considerably "more to learn" than the adults. Similarly, if females at a given age are, on the average, less experienced in movement than males, then it may be that females behave as though they are "younger," in a movement sense, than males. Perhaps as a result of some lack of movement experiences, the rules that relate the movement parameters to the movement outcomes (the schemas) are less well developed than they are in males, so that the females profit by practice variability in these experiments more than the males do.

But why might schema learning be better under random-practice as compared to blocked-practice schedules? It is this issue to which we now turn our attention.

Contextual Interference: Blocked Versus Random Practice

The focus of the preceding section was the effectiveness of practice on a variety of tasks relative