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 to practice on only one task variation, as measured in retention and transfer tests (i.e., tests of learning). The issue here is related: assuming that variable practice is probably better for retention and transfer, the question we will address is whether or not it makes a difference how the variable practice is *scheduled*.

Contextual interference was used in chapter 10 as an example of how different interpretations of learning could be derived from studies involving periods of practice, retention, and transfer. Given that one has *X* tasks to practice (or *X* variations of a task) and *N* trials to conduct on each task, the issue of scheduling is how to order the *N* trials on each task.

Two extreme types of practice schedules have frequently been compared in contextual interference studies. *Blocked* practice involves practicing all *N* trials on one task before any practice is begun on another task. All *N* trials are then completed on the next task before practice begins on a third task, and so on, until all tasks have been practiced. *Random* practice involves the same number of tasks and the same number of trials on each task as in blocked practice. The difference is that in random practice a trial on one task (call it *task A*) may be followed by a trial on *task B*, then a trial on *task C*, and so on, until all *N* trials on all *X* tasks have been completed.

Consider golf practice at a driving range as an analogy. Suppose you plan your practice by dividing the bucket of 60 balls into, say, 20 shots each with a driver, a 5-iron, and a pitching wedge. Blocked practice would involve hitting all 20 balls with one club before switching to another club. Random practice would involve switching clubs after each shot. We could use many similar examples of blocked and random practice related to training sessions in industrial and rehabilitation settings.

We presented the results of the Shea and Morgan (1979) study in detail earlier (see Example: Blocked Versus Random Practice in chapter 10, and also figures 10.7, 10.8, and 10.9). To summarize briefly, blocked practice resulted in better performance during acquisition in comparison to random practice (figure 10.7). However, immediate and delayed tests of retention were performed much more rapidly after practice in a random acquisition schedule (figure 10.8). This difference between groups was larger when the retention trials were performed in a random sequence, although there was a difference even in a blocked retention order (figure 10.9). Thus, regardless of whether the retention test was to be performed under random or blocked conditions, it was always more effective to *practice* these tasks under random conditions. This is a curious finding, especially when we realize that the random condition in acquisition resulted in slower performance than the blocked condition. The finding certainly runs counter to the general idea that, in practice, we should always attempt to organize the conditions so that performance is maximized.

Research on contextual interference for learning motor skills was initiated with the study of Shea and Morgan, although a few isolated studies of practice-scheduling effects had been published earlier (see Chamberlin & Lee, 1993, for references). The Shea and Morgan study was influenced considerably by the theoretical insights of William Battig (see boxed text on page 304). Together, the work of these authors has made a substantial impact on research in motor learning during the past two decades. This research can be loosely divided into two categories: (1) studies that have attempted to address the generalizability of the random-blocked differences and (2) work that has tested hypotheses regarding why contextual interference effects occur in learning motor skills. We examine each of these issues next.

Generalizability of Contextual Interference

Issues about the *generalizability* of contextual interference effects might be rephrased to ask the question, "How much faith should I put in the implications arising from the Shea and Morgan study?" Should random and blocked differences be expected to emerge under a variety of different conditions, using different tasks, for different subjects, and so on? Overall, there is a rather wide generalizability to the contextual interference effect.

Task Influences

The original Shea and Morgan (1979) demonstration of the contextual interference effect used a task in which subjects were required to make patterns of arm movements by knocking over small wooden barriers. The goal was to complete the pattern accurately, and as fast as possible, in

W.F. Battig and Contextual Interference

Research in the area of contextual interference owes a debt of gratitude to William F. Battig. Throughout a distinguished career, this cognitive psychologist maintained an interest in memory and learning, frequently conducting studies using both verbal and motor tasks. Early in his research, Battig showed that factors that make a task more "difficult" for the subject enhanced remembering and transfer. For example, requiring (vs. not requiring) learners to pronounce nonsense "words" (e.g., XENF), whose letters corresponded to individual finger movements, made performance on *another* version of the finger task more effective (Battig, 1956).

Battig interpreted these and related findings in terms of the following statement: *intertask facilitation is produced by intratask interference* (Battig, 1966, 227). *Intra*task interference referred to the hinderance caused by attempting to keep multiple items in immediate memory at one time (e.g., the interference between the "word" pronunciations and the finger movements). By *inter*task transfer, Battig was referring to the transfer of learning to other, similar motor tasks. These findings ran counter to intuition, as we would expect that transfer to other tasks would be most effective if the first task had been learned under the most optimal conditions for performance.

But the field of psychology was not prepared to consider such radical ideas, perhaps because the concepts ran so counter to existing theories of memory and learning. Little attention was paid to these notions, even though Battig and his colleagues continued to publish more demonstrations of these counterintuitive findings (e.g., Battig, 1972; Hiew, 1977). A responsive chord was finally struck with the publication of his expanded ideas on *contextual interference;* in this paper, Battig (1979) presented a rather wide framework conceptualizing the findings that had been accumulated. These ideas were expanded shortly thereafter (Battig & Shea, 1980) within the realm of motor skill learning, in which Battig's influence has made a very important mark.

Battig identified two important sources of interference that could arise during practice. One factor related to the *order* in which multiple items were studied or practiced. If the same task was practiced repeatedly, then only this one task needed to be held in working memory, and interference should be *low*. However, if practice involved many switches between multiple tasks, then interference should be *high*. This source of interference has been the object of considerable study and is the focus of the present discussion on contextual interference. The other source of interference was the nature of the material to be practiced. If the items (or motor tasks) were quite similar, then the interference arising during practice would be *high* because of the increased confusion. Items or tasks that were quite different or distinct would cause low interference.

Above all, the most important element of the contextual interference arising from a set of tasks or items to practice was *how the learner responded to the interference*. Battig suggested that subjects respond to situations of high or low interference with correspondingly high or low levels of elaborative and distinctive processing. These ideas have been expanded by the work of John Shea and his colleagues and represent one of the primary explanations of the contextual interference effect.

response to a stimulus light. These findings have been replicated a number of times using similar task requirements (e.g., Del Rey, Liu, & Simpson, 1994; Lee & Magill, 1983b; Shea & Wright, 1991; Wright, 1991). Other laboratory studies have revealed similar random-blocked differences using tasks that emphasize the timing of actions (e.g., Lee & Magill, 1983b; Proteau et al., 1994; Wulf & Lee, 1993), perceptual anticipation (e.g., Del Rey, 1989; Del Rey, Wughalter, & Whitehurst, 1982), the regulation of force (Shea, Kohl, & Indermill, 1990; Shea et al., 1991), and error-detection capabilities (Sherwood, 1996), to list just a few.

In all of these laboratory tasks, the actions to be performed were relatively simple, leading some to question the potential value of this research for practical situations involving much more complicated, "real" tasks (e.g., Newell & McDonald, 1992). However, these reservations may be unfounded. A recent study by Tsutsui, Lee, and Hodges (1998) showed that random practice facilitated the learning of new patterns of coordinating bimanual limb movements. Kinematic analyses of the movements that were produced showed superior coordination skill for the newly learned patterns after random practice versus after blocked practice. The similarity of these findings to the results in studies using much simpler tasks suggests that contextual interference effects may indeed be generalizable to learning tasks involving daily activities.

Contextual interference effects have also been found in a number of applied studies, such as investigations on learning badminton serves (Goode & Magill, 1986; Wrisberg, 1991; Wrisberg & Liu, 1991), rifle shooting (Boyce & Del Rey, 1990), volleyball skills (Bortoli et al., 1992; but also see French, Rink, & Werner, 1990), and kayaking skills (Smith & Davies, 1995), as well as in a study of baseball batting (Hall, Domingues, & Cavazos, 1994). Subjects in most of these applied studies were novices in the skills to be learned, with the exception of those in the study by Hall, Domingues, and Cavazos (1994), who were college-level baseball players and thus already quite skilled at the task. All subjects in this study performed two extra batting-practice sessions per week for 6 weeks. The batting sessions involved practice in which the pitcher threw 15 fastballs, 15 curves, and 15 change-ups. Groups of batters received these pitches in either a blocked or a random order over the entire 6-week period. They also performed two transfer tests in which pitches were delivered in both random and blocked orders.

The results of the Hall, Domingues, and Cavazos (1994) experiment are presented in figure 11.8, including the results for a control group that did not receive the extra batting practice. This control group performed more poorly on the transfer tests than did either practice group, suggesting that the extra batting practice was

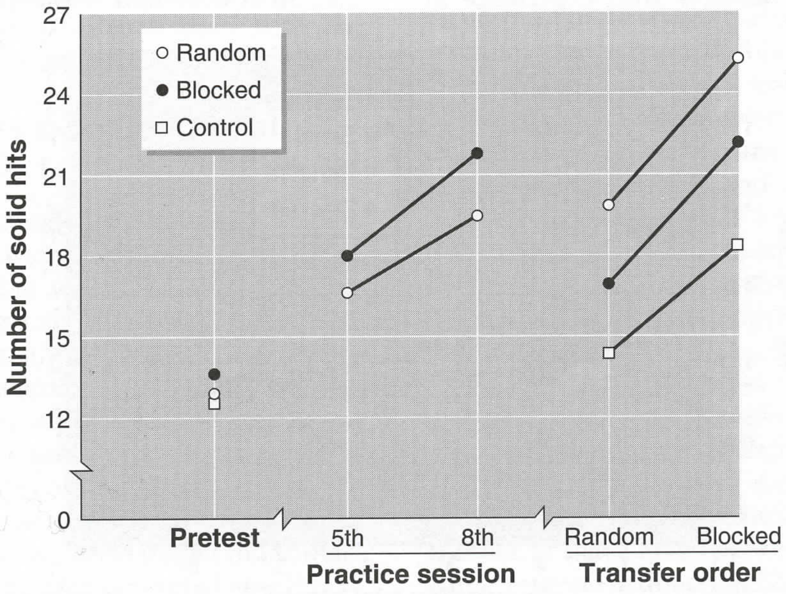

Figure 11.8. Contextual-interference effects in baseball batting.
Adapted and reproduced with permission of authors and publisher from: Hall, K.G., Domigues, D.A., & Cavazos, R. Contextual interference effects with skilled baseball players. *Perceptual and Motor Skills*, 1994, 78, 835-841. © Perceptual and Motor Skills 1994.

beneficial regardless of the order in which the pitches were thrown. However, the most interesting finding was the observed contextual interference effect in practice and transfer. Notice in figure 11.8 that the performances of the blocked group on the blocked transfer test and of the random group on the random transfer test were nearly identical to their respective performances in the eighth practice session. It was when performance was assessed on the *common* transfer tests that the true value of the practice sequences in learning came through, as random practice facilitated transfer under both orderings of pitches. Thus, it would appear from this study that even experienced athletes can benefit from random practice.

Subject Influences

In the preceding section we presented evidence that variability-of-practice differences were larger in children than in adults. The evidence relating to contextual interference effects is not quite as clear, however, as some studies have shown typical retention and transfer effects (e.g., Pollock & Lee, 1997; Wulf, 1991) whereas others have not (e.g., Del Rey, Whitehurst, & Wood, 1983; Pigott & Shapiro, 1984). There is some evidence that the magnitude of contextual interference effects may also depend on experience. Del Rey and her colleagues have shown, for example, that transfer in an anticipation task after random practice is facilitated more for subjects with experience in open skills than for novices (Del Rey, 1989; Del Rey, Wughalter, & Whitehurst, 1982).

Other Practice Schedules

Given X tasks and N trials per task, there is a wide variety of ways in which practice could be scheduled. Having *all* of the trials for one task performed in drill-type sequence represents an extreme scheduling manipulation. *Never* performing two consecutive trials on the same task might be considered the opposite extreme. A condition that might be considered "moderate," relative to these extremes, was examined by Lee and Magill (1983b). In their *serial* condition, practice was rotated among three tasks that were to be practiced, but always in the same order (e.g., B-C-A-B-C-A-B-C-A, etc.). Thus, practice was nonrepetitive, as in random practice, but the next task to practice was always predictable, as in blocked practice. As can be seen in figure 11.9, the performance of the serial group was nearly identical to that of the random group, leading to the suggestion that the repetitiveness of blocked practice may be the key factor that both facilitates acquisition and degrades learning.

An important question that arises is whether or not a practice schedule that represents some "middle ground" in terms of repetitiveness of practice might be beneficial to *both* performance and learning. Studies by Pigott and Shapiro (1984) and Al-Ameer and Toole (1993) support this

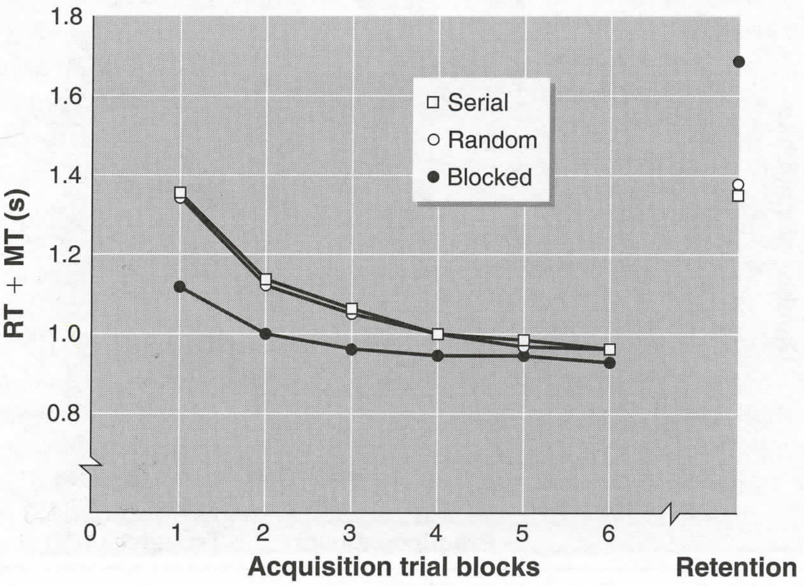

Figure 11.9. Comparison of blocked and random practice with a serial practice schedule.
Adapted from Lee and Magill, 1983.

possibility. In the Al-Ameer and Toole study, subjects practiced a task similar to that in the Shea and Morgan (1979) study under either random or blocked sequences. Results for both acquisition and retention replicated the Shea and Morgan findings. But Al-Ameer and Toole also added two groups that performed small *randomized blocks of trials,* in which a subject would practice one task for two or three trials, then randomly switch to another task and practice that for two or three trials. The results showed that randomized blocks of three trials facilitated acquisition performance (relative to random practice), and that randomized blocks of either two or three trials were just as beneficial to learning as random practice.

These findings are important, as they suggest that it may be possible to reduce the acquisition performance decrement normally seen with random practice without sacrificing the long-term learning benefit as a consequence. The results are also important for applying the findings from contextual interference experiments to tasks involving daily activities. One major drawback with a completely random schedule is that constantly switching from one task to another may be rather difficult. For example, consider tasks that involve training a new worker on specific job-related skills. If these tasks are located in separate rooms in a plant, it is logical to do at least *some* blocked practice before switching to a new task. The initial findings for the randomized-blocks schedule suggest that this condition combines many of the positive features from both the blocked- and random-practice schedules.

Hypotheses About the Contextual Interference Effect

Before the first contextual interference studies were published, learning researchers seemed to be quite comfortable with the general understanding that any practice variable that promoted acquisition performance would also promote learning. The findings of Shea and Morgan (1979) caused many motor learning researchers to become much less comfortable with this general understanding. How could a variable that slows improvement and retards the overall level of performance in practice be so potent in facilitating retention? This *paradox* generated new thinking and debate, not only about why contextual interference effects occur, but also with regard to the motor learning process in general. Several hypotheses have been advanced to explain the differences observed between random- and blocked-practice effects. And, though the hypotheses that follow may seem to present competing views, they really have much in common to say about the learning process.

Elaborative and Distinctive Processing Hypothesis

One of these hypotheses, proposed by Shea and colleagues, holds that random practice forces the learner into more *elaborative and distinctive* conceptual processing of the tasks to be learned (Shea & Morgan, 1979; Shea & Titzer, 1993; Shea & Zimny, 1983, 1988). During a random schedule, practice on one task is usually followed by practice on a completely different task. Thus, the preparation for action before movement and the evaluation of performance afterward may be quite different from the preparatory and evaluative processing that was completed on the previous trial. According to the elaborative and distinctive processing view, the differences in task requirements during random practice promote more *comparative and contrastive* analyses of the actions required to complete these tasks. As a result, the representation of each task following random practice is more *memorable* than in blocked practice, in which the opportunity for contrasting the different tasks is minimized because of the repetitive nature of the schedule. The advantages shown by random schedules in retention and transfer result from more *meaningful* representations of a given movement task and more elaborate distinctions between the various task versions.

Verbal reports from subjects involved in these experiments provide one line of evidence in support of the elaboration and distinctiveness hypothesis. Postexperiment interviews indicated that subjects in the random condition understood the tasks in a qualitatively different way than did subjects who performed blocked practice (Shea & Zimny, 1983). Compared to subjects in the blocked-practice group, subjects in the random group reported a much larger number of elaborate mental representations for distinguishing the shapes of the various movement patterns (e.g., noting that one pattern was essentially a mirror image of another, or that a given pattern was the only one with a reversal in direction; Shea & Zimny, 1983). In contrast, the blocked subjects reported that they tended to run the movements off without much thought, more or less "automatically."

Using a concurrent verbal report protocol, Zimny (reported in Shea & Zimny, 1988) found that subjects who were engaged in random practice made comments about specific tasks, as well as between-task comparisons, about twice as often during random practice as in blocked practice (see also Del Rey & Shewokis, 1993). These verbal report data support the superior contrastive value of random practice as predicted by the elaborative and distinctive processing hypothesis.

A different type of support for the elaborative and distinctive view was provided in a study in which random and blocked physical practice trials were alternated with three imagery practice trials (Gabriele, Hall, & Lee, 1989, experiment 1). For two groups, all three of the imagery trials were conducted on the task that had just been practiced physically (blocked imagery). In the other two groups, random mental practice involved imaging the three tasks that *had not* been performed on the preceding physical practice trial. Regardless of how the physical trials were practiced, random imagery facilitated retention more than blocked imagery, supporting the view that this contrastive processing during practice was beneficial for learning.

A more direct experimental manipulation was examined in studies by Wright (1991; Wright, Li, & Whitacre, 1992). Using an arm movement task similar to that employed by Shea and Morgan (1979), four groups of subjects all engaged in blocked practice. One group performed no additional processing, while subjects in the other groups performed certain cognitive activities between practice trials. After each practice trial, subjects in two of the groups were asked to describe verbally the order of movements of one of the tasks—either the task just completed or one of the other tasks. In the fourth group, subjects were asked to make specific comparisons between the task just performed and one of the other tasks. The prediction was that processing in this last condition would be most like the processing engaged in by subjects in random practice. The prediction was supported, as subjects in the intertask processing condition were better in retention than the other three groups. Interestingly, the additional processing in the other two groups with intervening cognitive descriptions did not improve retention at all, suggesting that the qualitative nature of the processing was more important than the quantity.

Forgetting and Reconstruction Hypothesis

A different explanation of the contextual interference effect was proposed by Lee and Magill (1983b, 1985), and is based on the ideas about the spacing effect presented by Jacoby (see boxed text on page 309). According to the *forgetting and reconstruction* view, the action planning that occurs just prior to a practice trial is influenced by what has been done in the previous trial. In blocked practice, a previously constructed action plan is available in working memory because the same task has just been performed. However, since tasks are ordered intermittently in random practice, the previously constructed action plan must be abandoned for the next trial(s) (in order to perform the other tasks) and must be *reconstructed* when that task is practiced once again. Thus, the value of a practice trial depends on the reconstructive processing undertaken. Remembering the "solution" from a previous trial (as in blocked practice) promotes good performance in acquisition, but does not promote the kind of processing that facilitates learning as measured in retention and transfer. In contrast, random practice causes forgetting, which is detrimental to acquisition performance but beneficial to retention and transfer.

Notice that this view of contextual interference follows the same logic as the spacing effect in memory (boxed text on page 309). In fact, there is evidence that memory for motor skills also shows a spacing effect (Lee & Weeks, 1987; Marshall, Jones, & Sheehan, 1977; Weeks et al., 1991). An important difference, however, is that the paradigm used to study the spacing effect is quite different from the learning paradigm that produces the contextual interference effect.

One prediction of the forgetting and reconstruction view that has been empirically tested in a learning paradigm relates to the cause of forgetting. The idea here is that on a given task, *any* activity between practice trials that causes short-term forgetting should promote learning. Note that this prediction is different from the elaborative and distinctive processing view, which suggests that distinctiveness arises from the similarity of different tasks in working memory during random practice. Several studies have examined this prediction; the evidence, though not strong, has been generally positive in support of the hypothesis (Lee & Magill, 1983a, 1987; Magill, 1988a; Young, Cohen, & Husak, 1993).

Larry Jacoby and the Spacing Effect

One of the puzzles about working memory is the curious statement that *"forgetting helps remembering"* (Cuddy & Jacoby, 1982). This statement sounds strange because forgetting (which we will discuss in chapter 14) is usually thought of as a *reduction* in the capability to remember; saying that "forgetting helps remembering" sounds like nonsense. However, the evidence from experiments on the *spacing effect* in verbal memory suggest that this statement is not as bizarre as it seems. In these experiments, subjects are typically given a long list of words that they are asked to study and to recall some time later on a test of memory. The list often comprises words presented only once as well as words that are presented more than once. For the words presented more than once, they may be repeated either immediately (a zero "lag" condition) or with a small or large number of intervening words. The spacing effect is the finding that recall of words that have been repeated with long lags is better than recall of words repeated with no lag or short lags.

Larry Jacoby (Cuddy & Jacoby, 1982; Jacoby, 1978; Jacoby & Dallas, 1981) proposed the idea that forgetting helps memory because the *processing* undertaken during study is determined by what is remembered about the material from the last processing of it. If the information is remembered well, then the material to be studied will not be fully processed on its second presentation. If the information has been forgotten, then the material will be more fully processed once again.

The critical issue for Jacoby is that the value of a repetition lies in the degree to which it promotes full processing of the information on *each* presentation. Processing information is similar to solving a problem. The results of the processing constitute a solution, much like the solution obtained by multiplying two numbers together. If the same problem arises soon after the solution has been determined, then the mental arithmetic need not be undertaken to solve the problem again because the solution is readily available in working memory. However, if the solution has been forgotten, then full processing must be undertaken in order to solve the problem again. Memory, according to Jacoby, is a product of the processing activities. "The means by which a solution is obtained influences subsequent retention performance: subsequent retention suffers when the solution is remembered" (Jacoby, 1978, p. 666).

A different approach to examining the forgetting and reconstruction hypothesis was tested in a study by Lee, Wishart, Cunningham, and Carnahan (1997). An important component of the prediction relates to the information in working memory when a trial is practiced. Instead of trying to induce forgetting, Lee et al. attempted to introduce into working memory the information necessary for the upcoming trial by means of a model. The rationale was that if the "solution" was present, then the problem-solving activity normally undertaken during random practice would be avoided. The experimenters used a timing task, with subjects making patterns of key presses on a computer keyboard. The random- and blocked-practice groups performed in acquisition and retention as expected. A third, *random plus model* group also practiced in a random order; however, the computer generated a visual map of the task along with an auditory template of the timing requirements three times before each pattern was practiced. The idea was that if the model *guided* the learner through the action-planning process, then the reconstruction benefits normally encouraged by random practice would be diminished.

The absolute constant error (|CE|) results are presented in figure 11.10. Two points of interest can be readily seen. First, even though practice was conducted in a random order, the performance of the group provided with modeled information was excellent. In fact, this random + model group outperformed the blocked group on the very first block of practice trials. And, as

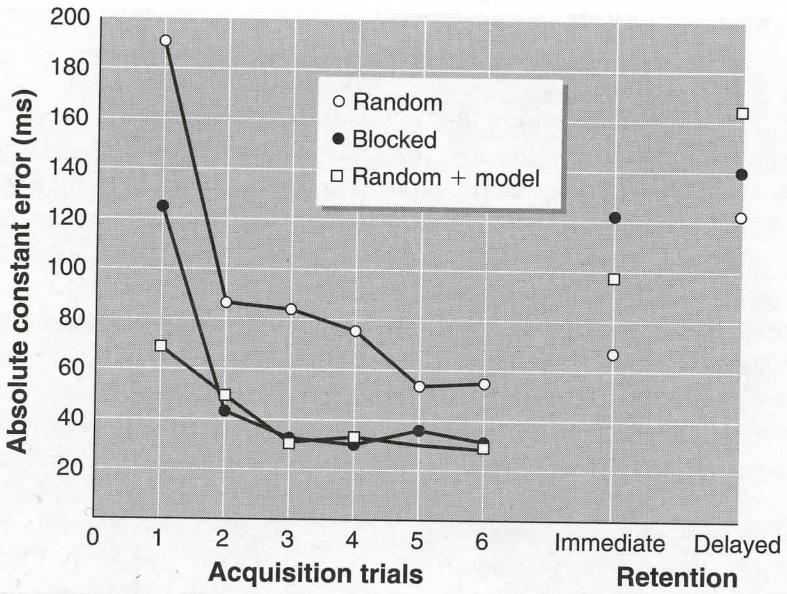

Figure 11.10. Elimination of the random-practice decrement in practice and the random-practice benefit in retention with a guiding model.
Reprinted from Lee, Wishart, Cunningham, and Carnahan, 1997.

expected, there was a strong negative influence of the model in immediate and delayed retention tests: the learning advantage normally seen following random practice was eliminated by the presence of the modeled information during practice.

One final research area that has surfaced with regard to the forgetting and reconstruction view deals with the nature of the planning activity. The hypothesis is that for random practice, the action prepared for one task is inappropriate for a completely different task and thus a new preparation is required. However, what happens if the "new task" has the same invariant characteristics as the previous task and requires only a different parameterization? According to the ideas presented in chapter 6, the same generalized motor program could be used with just a new scaling of movement parameters, thereby reducing much of the repreparation normally required by random practice. The prediction for tasks of this type would be a reduced contextual interference effect (Magill & Hall, 1990). Research on this specific prediction of the forgetting and reconstruction hypothesis has just begun, although the evidence at this point does offer support for the view (Hall & Magill, 1995; Lee, Wulf, & Schmidt, 1992; Wulf & Lee, 1993; but see also Sekiya et al., 1994).

Evaluating the Hypotheses

On balance, there appears to be considerable support for both the elaborative and distinctive processing account and the forgetting and reconstruction view of contextual interference. One of the problems in comparing these hypotheses is that there are few situations in which different predictions can be contrasted. Thus, the hypotheses should not be seen as *competing* predictors of the contextual interference effect, but rather as complementary theoretical views about the ways in which learners comply with the processing operations encouraged under different practice and task conditions.

Other Hypotheses

Of course, it is possible that future research will show that both the elaboration and distinctiveness and the forgetting and reconstruction views are wrong. Research on contextual interference effects is still rather new, and other hypotheses have been developed to account for these effects. For example, Wulf and Schmidt (1994a) argued that random practice is beneficial for learning because it makes KR *less useful* during practice—which, as we will discuss in chapter 12, is often a good strategy for learning. Others have suggested that the detrimental effect in retention occurs because of greater *retroactive inhibition:* the early tasks practiced by the blocked group are more difficult to recall because of the interference caused by practicing the other tasks in the interim (Del Rey, Liu, & Simpson, 1994; Shea & Titzer, 1993). Views that rely less on cognitive factors include suggestions that contextual interference effects arise as a *dynamic interaction* between the learner and the environment (Newell & McDonald, 1992) or within the constraints of *connectionist modeling* (Horak, 1992; Masson, 1990; Shea & Graf, 1994).

Practical Implications

Whatever the theoretical explanation for these curious effects, it is clear that they are present in both laboratory and practical situations, that they lead to relatively large differences in learning, and that they seem to represent stable principles of motor learning. As a result, they should have important practical implications for the design of learning environments in sport, industry, and therapy. The "traditional" methods of continuous drill on a particular action (i.e., practicing one skill repeatedly until it is correct) are probably not the most effective way to learn. Rather, the evidence suggests that practicing a number of tasks in some nearly randomized order will be the most successful means of achieving the goal of stable learning and retention. Of course, these findings highlight the learning-performance distinction discussed earlier in this and the preceding chapter; here we have a situation for which the conditions in acquisition that make performance most effective (blocked practice) are *not* the most effective for learning—an important general consideration for those designing workable practice sessions. Although the application of these ideas is strongly implicated (Dempster, 1988; Goettl, 1996), much work remains to be done on these issues with different kinds of tasks and various training settings before we can be confident about how to effectively apply these principles.

Mental Practice

Hypotheses regarding the contextual interference effect relied heavily on concepts regarding mental operations to explain the rather paradoxical relation between acquisition and retention effects. In fact, in a number of the experiments described in the previous section, the effects on physically practicing the task in a random or blocked order were influenced considerably by the way in which the subject was directed to think about certain tasks or activities. For example, Wright (1991) showed that blocked practice was enhanced by asking subjects to mentally compare the set of tasks to be practiced. Similarly, Gabriele, Hall, and Lee (1989) found that mental imagery added a boost to retention performance when combined with physical practice. These are examples of a broader phenomenon in the motor skills literature known as *mental practice effects*. In general, mentally practicing a skill (i.e., imagining performing it, without any associated overt actions) can be shown to produce large positive transfer to skill in the actual task. These techniques, sometimes referred to as *covert rehearsal*, have been studied extensively throughout this century.

Is Mental Practice as Effective as Physical Practice?

Experimental assessment of mental practice effects usually requires several different groups of subjects, at a minimum. All subjects are given a pretest on a task to be learned, followed by the experimental manipulation, then a posttest on the learning task. The mental practice manipulation often entails a covert rehearsal of the task, sometimes involving certain strategies (such as imagery techniques). In this case, however, learning due to only mental practice effects cannot be inferred from only a retention test. Rather, in order to show that mental practice was effective, one must demonstrate that performance on the posttest exceeded performance in a control group that did not perform intervening practice or that performed practice on an unrelated task. In addition, mental practice is usually compared to a third condition in which a group of individuals *physically* practice the task for the same amount of time as the mental practice group. Some experiments also include *combination* conditions; here a group of subjects alternates between trials of mental and physical practice. Of course, many experiments use other variations of these mental practice manipulations, reviewed most recently by Feltz and Landers (1983; Feltz, Landers, & Becker, 1988).

A very nice demonstration of all these various practice conditions is provided in a complex study by Hird et al. (1991). Twelve groups of subjects participated in the experiment. Six groups were asked to learn a pegboard task, inserting pegs of different colors and shapes as rapidly as possible into squares cut in a board. The other six groups performed the pursuit rotor task. For each task,