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, subjects performed a pretest, seven sessions of training (on separate days), and a posttest. During the training sessions the 100% physical practice group performed eight trials on the task while the 100% mental practice group covertly practiced the task for the same amount of time. Three other groups performed combinations of practice, consisting of two, four, or six trials of physical practice combined with six, four, or two trials of mental practice (i.e., 75% physical practice [P]:25% mental practice [M]; 50P:50M; and 25P:75M groups). The control group performed on an unrelated task (the stabilometer) for the same amount of time during these training sessions.

The difference in performance between the pretest and posttest for each group in the Hird et al. study is presented in figure 11.11. The sets of findings for the two tasks are remarkably similar. The groups given mental practice (100%M) were more effective than the no-practice (control) groups, but not nearly as effective as the groups given the same amount of physical practice (100%P). In addition, the results for the combination groups showed that learning was enhanced with higher proportions of the training trials spent in physical, compared to mental, practice (e.g., compare the 75P:25M groups with the 25P:75M groups in figure 11.11).

The Hird et al. (1991) findings are in complete agreement with the reviews of the mental practice literature conducted by Feltz and Landers (1983; Feltz, Landers, & Becker, 1988). The findings suggest that *whenever possible*, physical practice is preferable to mental practice for learning. However, when physically practicing a task is not possible, mental rehearsal is an effective method for augmenting a subject's learning.

Hypotheses About Mental Practice Effects

Why then, is mental practice effective for learning a motor skill? Certainly, one of the components of mental practice involves learning the *cognitive elements* in the task; that is, learning what to do (Heuer, 1985). Given the requirement of rehearsing mentally, the learner can think about what kinds of things he or she might try, can predict the consequences of each action to some extent on the basis of previous experiences with similar skills, and can perhaps rule out inappropriate courses of action. This view suggests that not very much motor learning is happening in mental practice, the majority being the rapid learning associated with the cognitive elements of the task. Such a view fits well with data from Minas (1978, 1980), who used a serial throwing task in which subjects had to throw balls of different weights and textures into the proper bins. The main finding was that mental practice contributed to the learning of the sequence (the cognitive element) but did not contribute very much to the learning of the particular throwing actions (motor elements).

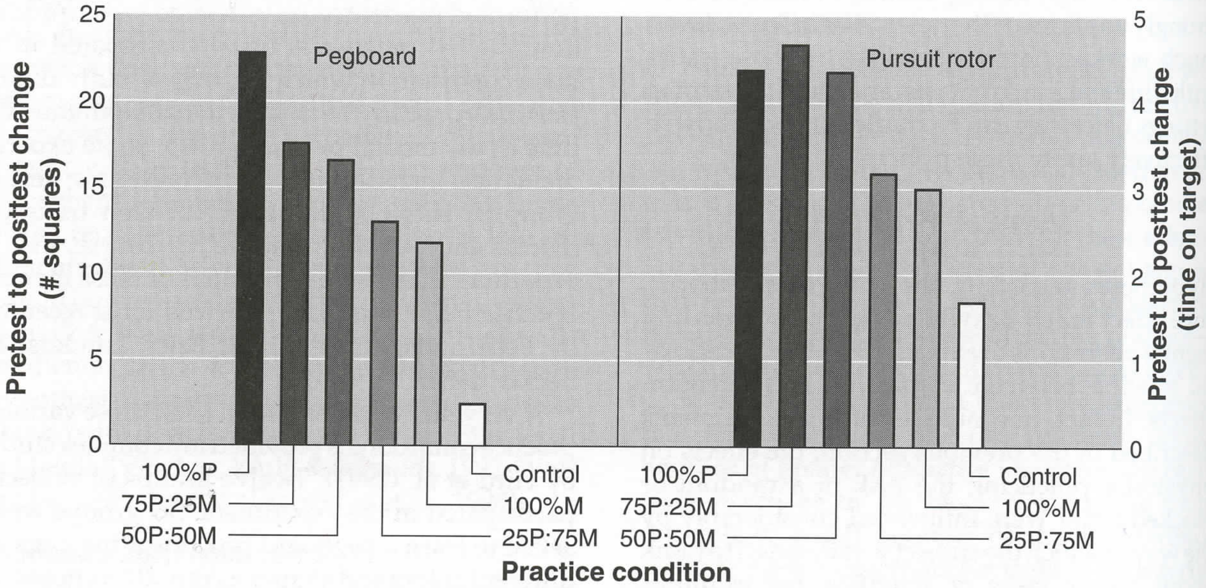

Figure 11.11. Effects of various combinations of physical and mental practice on pegboard and pursuit rotor tasks. Adapted from Hird, Landers, Thomas, and Horan, 1991.

But others think that there is more to mental practice than this simple view about learning the cognitive elements in a task. One view is that the motor programs for the movements are actually being run off during mental practice but that the learner simply turns down the "gain" of the program so that the contractions are hardly visible. Research on so-called *implicit speech,* in which subjects are told to imagine speaking a given sentence, shows patterns of electromyogram activity from the vocal musculature that resemble the patterns evoked during actual speech. One possibility is that very small forces (not sufficient to cause movements) are produced and the performer receives Golgi tendon organ feedback about them (chapter 5), as the Golgi tendon organs are extremely sensitive to small forces. Another possibility is that the "movements" are sensed via feedforward and corollary discharge (i.e., "internal feedback"), generated when the motor programs are run off (chapter 5). Yet another possibility discussed earlier in this chapter is that *planning* a movement (which should be part of mental practice) is itself beneficial to learning. Unfortunately, there is little evidence available to distinguish among these hypotheses (see Heuer, 1985, for a detailed discussion).

Part Versus Whole Practice

A very common technique for teaching motor skills is to break them down into smaller parts, to eliminate the burden of repeating the simpler parts of the entire task. Also, this would seem to be an effective procedure when the task is very complex and cannot be grasped as a whole. Examples are numerous, such as practicing separately the arm and leg strokes in Red Cross swimming methods and practicing specific stunts in gymnastics that later become part of a larger routine.

The ultimate test of whether or not these methods are effective is the amount of transfer that can be shown from the practice of the part to the performance of the whole task. It seems obvious that if practice is given on the part, it would certainly transfer highly to the whole task, as the part would seem to be identical to one element of the whole. The problem with this idea is that practice on the part in isolation may so change the motor programming of the part that for all practical purposes it is no longer the same as it is in the context of the total skill. It turns out that whether or not part-whole practice is effective depends on the nature of the task (Wightman & Lintern, 1985).

Serial Tasks

Seymour (1954) conducted extensive research on industrial tasks that are serial in nature. One task consisted of a series of elements to be performed on a lathe. Some of the elements were difficult, requiring a great deal of practice to master; some were easy and could be accomplished on the first try. Seymour found that if the difficult parts were practiced separately, without any corresponding practice on the less difficult parts, there was considerable transfer of the part to the whole task. Similar findings were produced by Adams and Hufford (1962), who studied part-practice of various discrete actions involved in aircraft flying. More recent examples involve learning special multicomponent video games designed especially for research purposes (Mané et al., 1989). In these cases, transfer from part-practice can be *greater than* 100%, in that the benefits afforded by some amount of practice on the parts in isolation can be greater than those obtained with an equal amount of time devoted to the whole task (see also Newell et al., 1989; Wightman & Sistrunk, 1987).

According to one way of viewing these effects, in part-task practice the learner does not have to spend time on the parts of the task that have been already mastered, and the practice is more efficient. The task can be reassembled in many ways, of course, but an efficient method is *backward chaining,* in which the last element in the sequence is systematically preceded by earlier and earlier parts until the whole chain is completed (Wightman & Lintern, 1985; Wightman & Sistrunk, 1987). Mere practice on a part isolated from the sequence does not appear to be as useful for transfer (Sheppard, 1984).

Continuous Tasks

For continuous tasks, in which the behavior continues more or less uninterrupted (as in walking or steering a car), the parts that can be isolated frequently occur at the same time as other parts. This is, of course, in sharp contrast to the situation for serial tasks, in which discrete parts are sequentially organized. Also, in continuous tasks the parts must frequently be *coordinated* with each other; and it might seem that breaking into this