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 pattern of coordination to practice a part might not be highly effective, as it is the coordination between these parts that must be learned. Swimming strokes have this characteristic, as the arm strokes, breathing, and kicking actions must be coordinated to form an effective whole.

Briggs and Brogden (1954) and Briggs and Waters (1958) used a lever-positioning task that required positioning in two dimensions (forward-backward, left-right) simultaneously and continuously, much like the positioning of the "joystick" that is done in an airplane to control the motions of the plane. They found that practice on the separate dimensions alone transferred to the whole task, but that this practice was less effective than practicing the whole task for the same period of time. It is possible that the most effective way to learn such tasks is to practice the whole, unless the task is highly complex or contains rather trivial elements.

Another situation that produces slightly different findings involves those tasks in which the parts *interact* while they are being performed simultaneously. One complex example involves the operations necessary to take a helicopter from the ground into flight. According to Zavala et al. (1965), the operator must handle four separate controls. The first is a *cyclic pitch-control stick*, which is really a stick control for two dimensions in one (roll and pitch). When moved in a particular direction, it causes the helicopter to tilt in that direction. Thus, it can be used to control roll (side to side) and pitch (nose up or down) simultaneously. Second, a *collective pitch lever* is mounted to the left of the pilot, and up-and-down movements of this lever control the vertical component of the flight. Third, a *throttle* is located as a twist grip on the pitch control just mentioned; it controls the engine speed in the same way the accelerator in an automobile does. Fourth, *antitorque pedals* under the pilot's feet control the pitch of the small propeller at the tail of the helicopter, thus controlling the direction of the plane and compensating for the torque produced by the overhead rotors.

The problem for the person learning this task is that these components interact strongly. That is, when the throttle control is used to speed up the rotor or the pitch control is adjusted, there is a tendency for the helicopter to turn in the direction opposite the rotation of the rotor. This must be counteracted by an appropriately graded foot-pedal movement to maintain the proper heading. But also, the helicopter will increase its tendency to roll and attempt to dive; both of these motions must be counteracted by the adjustment of the cyclic-control stick. Thus, when the lift of the rotors is increased in the attempt to get the plane into the air, three other adjustments must be made simultaneously to prevent it from turning upside down. The amount of control change in these three dimensions depends on the amount of lift that is imparted to the helicopter via the other pitch control. It is said that these control dimensions interact because the setting of one of them will depend on the setting applied to the others.

It would be tempting to take this highly complex task and break it down into separate parts. But this breakdown seems to sidestep the most important problem for the learner: how to coordinate these actions. Any one of the dimensions can easily be performed separately, but this practice would not be very effective for learning the total task. In general, the limitations of part-to-whole transfer methods will probably depend on the extent to which the parts of the task interact within the whole task. As for the helicopter, it would seem that an effective way to learn the task would be to practice in a ground-based simulator, where all dimensions would be learned together without the fear of an accident (see more on *simulators* in chapter 14).

Discrete Tasks

Can we apply this evidence about part versus whole practice to discrete tasks whose MTs are very short (e.g., less than 1 s)? Probably not, as the evidence gives a different picture in these situations.

For example, Lersten (1968) had subjects learn a hand movement task (the rho task) that required a rapid movement with two components. The subject grasped a handle and rotated it in the horizontal plane through 270° until it hit a stop, whereupon the subject was to release the handle and move forward to knock over a barrier. This was to be done as quickly as possible (MTs were about 600 ms). Thus a circular component was followed by a linear component, both of which could be practiced separately by various groups. Another group of subjects practiced only the whole task. Lersten found that practice on the circular component alone transferred only about

7% to the performance of the circular phase in the context of the whole task. Other conditions produced no transfer to the whole task. Even more important, Lersten found that the practice on the linear component alone transferred *negatively* (about –8%) to the whole task. That is, practicing this linear component in isolation produced less learning on the whole task than not practicing at all! Overall, the findings suggest that practicing these isolated components of the whole task produced essentially negligible transfer to the performance of the whole task.

Sequential Parts

How can these findings be explained? First, even though the task Lersten used was "serial" in nature, it must be seen as quite different from the serial tasks used by Seymour (1954). One clear difference is in terms of the overall MT, with Seymour's tasks having durations in the order of minutes and Lersten's task lasting for only about 600 ms. It seems reasonable to assume that Lersten's task was governed by a single motor program containing the instructions for both the circular and the linear components, as well as the instructions for the transition between the two (timing the release of the handle, for example). If so, then practicing the circular part in isolation would result in the subject's practicing a program different from that involved in the circular part within the context of the whole skill, because the circular part did not entail a handle release. In contrast, the serial tasks that Seymour (1954) used can be thought of as a series of programs strung together. Practicing one of them in isolation is the same as practicing that program in the context of the total skill, so part-to-whole transfer is high.

These ideas suggest that the major determinant of whether or not part-to-whole transfer will "work" is the extent to which the movement is governed by a single program. If the movement is very fast, it will almost certainly be governed by one motor program, and it should be practiced as a whole. Second, if the movement is slower but there is a "break" in the action that is easily adjusted, it is possible that the movement is governed by more than one program. An example is the break between the toss action and the hit action in a tennis serve; the toss seems programmed, but then there is a feedback-based break so that the hit program can be adjusted to the exact location and timing of the ball toss. In a springboard dive, the takeoff and tuck are probably programmed, but the timing of the "untuck" movements must be feedback based, determined by visual or vestibular information. These tasks could probably be split into their component parts for separate practice, and part-to-whole transfer would probably be higher.

Simultaneous Parts

A second situation is that in which the parts of the task are simultaneous, rather than serial as in Lersten's example. Many examples exist, such as playing the piano (left and right hands) or any other task for which one part of the body has to be coordinated with another. Transfer research on these questions is nearly nonexistent, though, and the decisions about part-whole transfer are mostly speculative.

First, it seems from the data presented in chapter 8 that rapid, discrete two-handed simultaneous movements must be controlled by a single program, with the program containing instructions for both hands. Practicing the movements of one hand in isolation probably results in the development of a different program than practicing that "same" movement in the context of a total two-handed skill. Konzem's (1987) data suggested that the program to make a "V" with the right hand was probably different from the program required to make a "V" with the right hand and a "γ" with the left hand simultaneously. The principles underlying coordination of the separate limbs in an action are not well understood, and more work on this is needed; but it seems clear that breaking down a task into its components will not always result in large part-to-whole transfer.

Lead-Up Activities

A closely related question for the teaching of skills concerns the use of so-called lead-up activities. In these situations, certain simpler tasks are thought to be in some way fundamental to the learning of more complex tasks, so the simpler tasks are formally taught as a part of the procedure for learning the more complex task. These procedures are often used in gymnastics as the instructors talk of a progression of subtasks leading eventually to the complex goal response. The question, again, can be thought of as one of transfer from the lead-up task to the goal movement. Such activities might have the disadvantage of being, by necessity, different from the goal action, and the motor transfer from them could be very small. Certainly this conclusion is in keeping with the evidence on transfer. But, unfortunately, no effective experiments on lead-up activities can be found, so this conclusion has to be seen as speculative.

On the other hand, lead-ups may have many positive aspects. First, in many tasks (e.g., stunts in gymnastics) there is a strong element of fear. Lead-ups, being simpler and less dangerous, may serve a useful role in reducing fear responses that can be detrimental to a more complex movement. This fear-reduction aspect is borne out in studies using "desensitization techniques," whereby people are taught to eliminate phobic responses (e.g., fear of snakes, or heights) by performing lead-up activities that bring them progressively closer to the target fear (e.g., progressively more "realistic" snakes, eventually leading to an actual snake; see Bandura, 1969, or Bandura, Blanchard, & Ritter, 1969). Also, many lead-ups are designed with a particular action in mind. In gymnastics, again, the "kipping" action (a forceful, timed extension of the hip) is thought to be involved in a large number of skills. Learning to kip in one simple lead-up activity possibly will transfer to the "same" action in a more complex and dangerous activity.

Guidance

A technique frequently used in teaching and in rehabilitation involves *guidance,* whereby the learner is in some way guided through the task to be learned. Actually, guidance refers to a variety of separate procedures, ranging from physically pushing and pulling the learner through a sequence, to preventing incorrect movements by physical limitations on the apparatus, or even to the simple act of verbally "talking someone through" a new situation. These guidance procedures tend to prevent the learner from making errors in the task.

What does the evidence on guidance suggest? Much of the research on guidance by Holding (1970; Holding & Macrae, 1964; Macrae & Holding, 1965, 1966), Singer (1980; Singer & Pease, 1976; Singer & Gaines 1975), and others (reviewed by Armstrong, 1970a), using various tasks and guidance procedures, shows considerable positive effects of guidance procedures on performance during acquisition. We should remember, however, that guidance will usually have, by definition, strong effects on *performance* during the trials in which it is administered. Of course, as we have discussed previously, performance gains during acquisition may not represent relatively permanent changes attributable to learning, and the important question is whether such performance gains will survive a transfer test in which the guidance is removed.

One of the definitive studies in this area was performed by Armstrong (1970b). He compared various forms of physical guidance in a task for which the learner had to make an elbow movement having a complex spatial-temporal pattern (see figure 6.17), with MTs of 3 or 4 s. Three of his groups are of specific interest here. One group practiced the task and received terminal, kinematic feedback (knowledge of performance [KP]) after each trial. In addition, after the last in a block of 15 trials, subjects in this group were shown a plot of their last trial in combination with a template of the goal pattern. Another group was given concurrent visual feedback of both the movement being made by the subject and the movement of the template as it was traced on the monitor. In a third group, the movement device moved by the subject was mechanically controlled such that any deviations from the target path were physically corrected. Practice was conducted over 3 days, which also included a transfer test on the third day during which all subjects performed the task with no augmented information. The results, presented in figure 11.12, were very dramatic. As can be seen, the guidance device restricted errors so that performance was nearly perfect throughout the entire practice period. The concurrent feedback was also quite effective in reducing performance error during practice—clearly not as effective as the guidance device but much better than the terminal feedback. But Armstrong's results showed that the guidance effects provided only temporary boosts to performance. As can be seen on the right side of figure 11.12, the transfer trials were performed best by the terminal-feedback group, and very poorly by both the guidance and concurrent-feedback groups. In fact, the latter two groups