CHAPTER FOURTEEN

Training Complex Psychomotor Performance Skills*

A Part-Task Approach

Peter J. Fadde

This chapter focuses on training complex psychomotor performance skills, advocating a part-task approach that involves de-coupling the conjoined cognitive and motor domains for targeted training. Psychomotor performance skills typically include two types of component skills: *production* of motor actions and *recognition* of environmental conditions that trigger actions. Production and recognition skills are often intertwined in a seamless cycle of adaptive action that appears effortless when observed in an expert performer—whether that is a surgeon performing an arthroscopic ligament repair, a head sawyer segmenting a log to maximize the lumber footage, or a linebacker in American football knifing into the backfield to make a tackle-for-loss.

Despite the intertwined nature of the production and recognition components of psychomotor performance, there are benefits to keeping them artificially separated for the sake of targeted *part-task* training. Actually, it is quite typical of psychomotor training approaches to isolate and target production skills for part-task training, often using behavioral principles of chaining small, sequential steps or shaping a skill sequence from simple to complex. Newer theories of training psychomotor performance in sports favor *decision training* over

* *Note:* I would like to thank Edward Fadde for providing inspiration and expertise for the semi-truck driver training scenario that is portrayed in this chapter.

behavioral motor training (Vickers, 2007). Decision training entails incorporating recognition skills earlier in the acquisition and practice of psychomotor production skills, for instance, having a quarterback in American football practice reading defenses while practicing footwork drills. More traditionally, integrated training of recognition and production components of psychomotor skills occurs during whole-task practice. However, whole-task practice can be expensive and instructionally inefficient. Full team football scrimmages, for example, produce much less coaching of individual players than small-group drill periods. Instructional inefficiency, along with increased risk of injury in competitive play, is why college football coaches typically minimize the number and length of full-contact team scrimmages (J. Tiller, personal communication, May 24, 2003).

While whole-task practice, including high-fidelity simulation, is assumed to facilitate transfer of learning to performance, high instructional costs suggest that it should be used judiciously (Alessi & Trollip, 2001). In many cases, it can be instructionally efficient to keep the production and recognition components of psychomotor skills separate for the sake of targeted training activities that are optimized for either the psycho or the motor part and are therefore more efficient. This part-task approach to training psychomotor performance skills is based on the simple but profound notion that recognition and production components can be de-coupled for targeted training and then re-coupled for transfer to performance.

The part-task production/recognition approach to training psychomotor performance skills is based on sports science research showing that experts' performance advantage over skilled but less expert performers often lies in the area of recognition skills rather than production skills and, further, that recognition skills can be targeted for part-task training that then leads to improved performance of the overall skill (Williams & Ward, 2003). The part-task training approach has far-reaching implications for training psychomotor performance skills beyond sports, especially those that are typically associated with simulator-based training such as aviation, surgery, and use-of-force in law enforcement and the military (Fadde, 2007).

CHAPTER PLAN

Before exploring the part-task production/recognition training approach, I summarize eight principles for training psychomotor performance skills. These principles are drawn primarily from the sports area and include both traditional and newer approaches. I then list guidelines for designing psychomotor training in a distinctly non-sports domain. The guidelines are based on the *2002 National Guidelines for Educating Emergency Medical Service (EMS) Instructors* (NHTSA, n.d.). The EMS training guidelines relate to a particular type of psychomotor training that is common in corporate, educational, and military contexts—that is, procedural training of adult professionals in a group workshop environment.

I then return to the part-task training of the production and recognition components of complex psychomotor performance skills. The theory and methods that support the part-task approach come from expertise research in the field of sports science, which I will review. I then outline an extended scenario that draws on the provided principles and guidelines of psychomotor training as well as the emerging sports science research on recognition training. The scenario involves designing a part-task production/recognition training program that is intended to improve the truck backing skill of over-the-road truck drivers. The production skills training component is designed to be completed at a closed-course training facility, while the recognition training component is designed to be delivered over the Internet.

PRINCIPLES OF TRAINING PSYCHOMOTOR PERFORMANCE SKILLS

Derived largely from established theories of motor learning (Schmidt & Wrisberg, 2004) and newer theories of sports coaching (Vickers, 2007), these eight principles of training psychomotor performance skills relate to practice scheduling, provision of instruction, the learner's focus of attention, feedback provided to learners, the role of feedback in simulation, and technology-based feedback. The principles recommend using:

1. Blocked practice for faster initial learning; spaced practice for better retention and transfer; decision practice for highly motivated learners;
2. Explicit instruction for faster initial learning; implicit instruction for better retention and transfer;
3. Internal focus of attention for initial learning; external focus of attention for more skilled performers;
4. Knowledge-of-performance feedback early in skill development; knowledge-of-results feedback later; fade feedback as skills develop;
5. Artificial simulation feedback early in learning; natural simulation feedback later in learning;
6. Constant, augmented feedback for initial learning; delayed augmented feedback (such as video) with more advanced learners;
7. Questioning by trainer to help advancing learners develop self-coaching; and
8. Part-task drills to train recognition skills separate from motor skills.

Practice Scheduling

The key decisions in designing practice schedules include: blocked or variable, concentrated or spaced, component or whole-skill, and chaining or shaping. Initial training of motor skills has a long tradition of relying on blocked practice of component sub-skills. For instance, each stroke in tennis has component motor skills such as footwork, grip, backswing, and striking motion. These might be taught in sequence (forward chaining): grip followed by footwork followed by backswing followed by striking motion. Alternatively, component sub-skills might be practiced through reverse chaining whereby the learner is "given" proper footwork, grip, and backhand and then practices executing the ball strike—giving the learner the satisfaction of a well-executed stroke, and then retracing to practice the individual components that led to it.

Component sub-skills might also be taught in an easy first sequence. This approach might also start with the striking motion because that is what is most natural (easiest) for beginning players. The training sequence might go next to footwork or backswing—whatever is the next-easiest or most natural for the player. Such a sequence might focus on grip last because it is likely to be the most abstract component for a novice player. In any case, *chaining* involves individually mastering component sub-skills through blocked practice trials.

Another alternative for initial learning and practice of motor skills is *shaping* of a learned motor skill sequence in which the learner practices a particular stroke (serve, volley, forehand, backhand) as a complete sequence but begins with a simplified performance context such as a coach tossing the ball so that it bounces to the location at which the learner is oriented to strike the ball. Practice of the full stroke would then progress through increasingly difficult ball-striking contexts.

Once a number of strokes are learned completely, if not yet refined, then the issue of blocked versus variable practice arises. A tennis player might practice serve, return of serve, volley, backhand, forehand, overhead, and drop shots in a single practice session, each in a distinct *block* of practice trials. Alternatively, a practice session might be arranged so that the player hits a few serves followed by a few volleys followed by a few overheads, and so on in a *variable* practice sequence. Or a coach could hit a ball toward the practicing player and then call out which stroke the player is to execute while the ball is still approaching to create *random* practice.

Newer theories of coaching advocate using contextualized *decision practice* that moves away from part-task drills and toward whole-task practice. Also called *hard first* practice because it incorporates complex situations right from the earliest practice sessions, this approach might have a developing tennis player practice shots in game-type sequences, for example, serve, approach, volley, and overhead shots in succession. Research shows that whole-task practice leads to slower immediate learning but better retention and transfer of learning to performance (Vickers, 2007).

Vickers conducted a study involving batting practice with college baseball players in which a *behavioral training* group practiced hitting the same type of pitch (fastball, curveball, or changeup) in blocks of fifteen pitches. A *decision training* group hit the same number of pitches, but with the types of pitches mixed randomly—much as in game conditions. The behavioral group showed greater improvement in early practice sessions, while the decision training group actually suffered a decrement in performance compared to baseline during early practice sessions. Only after eight practice sessions did the decision training group catch up to the behavioral training group. Ultimately, though, the decision training group performed better than the behavioral training group on retention and transfer tests that involved hitting mixed pitch types. Decision training, then, appears to have long-term benefits but comes with a steep learning curve that requires highly motivated coaches or trainers as well as learners.

In addition to questions of scheduling drills within a practice session, there are also scheduling options between practice sessions. Blocked or concentrated practice sessions are contrasted with *spaced* practice sessions. A developing tennis player, for example, might practice for six hours in a single session, or the player might practice for two hours in each of three separate sessions.

In general, spaced practice is considered superior to concentrated practice, variable practice superior to blocked practice, and whole-task practice superior to component practice. However, each different practice schedule may be more or less appropriate for particular learners and learning goals. For example, blocked practice is known to be less than optimal for retention and transfer—which are usually the goals of training. However, blocked practice may be called for in situations in which learners are resistant to training or lack confidence and therefore need quick and observable results to remain motivated. While general principles of optimal practice can be supported, the informed teacher, trainer, or instructional designer doesn't reject any of the options for practice scheduling outright but rather picks and chooses among practice schedules based on the present learners, goals, and context.

Principle 1: Blocked Practice for Faster Initial Learning; Spaced and Variable Practice for Better Retention and Transfer; Decision Practice for Highly Motivated Learners

Instruction. In many ways, the contrast between traditional behavioral practice and more recently articulated decision practice represents the continuing debate in learning science between direct instruction and situated or constructivist learning. Both approaches have strengths and weaknesses that recommend them in particular contexts and with particular learners. A similar contrast can be made between explicit instruction and implicit instruction. A study that involved teaching intermediate tennis players to recognize pre-serve cues shown by an opponent server found that a group given explicit instruction in what cues to look for had better initial success. A comparison group that was given implicit instruction on *where* to look but not what to look for had less initial success but ultimately better retention of the skill (Smeeton, Hodges, & Williams, 2005).

Principle 2: Explicit Instruction for Faster Initial Learning, Implicit Instruction for Better Retention and Transfer

Learners' Focus of Attention. In another study of batting practice by college baseball players, one group was directed to focus on the internal production of motor movement and another group was directed to focus on external knowledge of results (Castaneda & Gray, 2007). The researchers found that more skilled batters performed best with an external focus of attention and were hampered by an internal focus on execution of skills that were already mastered to a point of largely unconscious control. Alternatively, less skilled batters performed better when focusing attention internally on execution of skills.

Principle 3: Internal Focus of Attention for Initial Learning, External Focus of Attention for Skilled Performers

Feedback. Feedback can be described as internal (also termed intrinsic or inherent) feedback—which is natural feedback from our senses—or external (also termed extrinsic or augmented) feedback—such as that provided by viewing videotape or a coach's comments. Internal, kinesthetic feedback in psychomotor skills is often an issue with patients recovering from injury or illness (Schmidt & Lee, 2005). Internal feedback is also an essential aspect of developing expertise in golf, diving, gymnastics, and other *closed* sports and non-sports skills in which the goal of performance is to execute skill sequences as precisely as possible with relatively little adjustment for the actions of an opponent or changes in the environment. Such closed skills are less the focus of this chapter than *open* skills that still involve performers executing skill sequences but also dynamically adapting skill execution depending on actions of an opponent or changing environmental conditions.

Extrinsic/augmented feedback provided by a coach during or after performance is one of the key strategies involved in the design of psychomotor training. While it has long been the tradition of sports coaching to provide abundant levels of corrective feedback to performers at all levels of skill, research now favors *bandwidth feedback* that involves reducing and delaying feedback as a learner's skill level increases (Vickers, 2007). Interestingly, bandwidth feedback is consistent with the behavioral principle of fading reinforcement as a behavior is strengthened. Schmidt and Lee (2005) state that "When augmented feedback is provided frequently, immediately, or otherwise in such a way that various processing activities are not undertaken, then there will likely be a decrement in learning" (p. 398).

Extrinsic/augmented feedback can be in the form of *knowledge of results* or *knowledge of performance*. The Castaneda and Gray (2007) baseball batting study suggests that externally focused knowledge-of-results is a more appropriate mode of feedback for skilled learners, and internally focused knowledge-of-performance feedback is more appropriate for less skilled performers.

Principle 4: Knowledge-of-Performance Feedback Early in Skill Development; Knowledge-of-Results Later; Fade Feedback as Skills Develop

Simulation Feedback. Training of psychomotor performance skills often includes simulation of performance situations during whole-task practice. Feedback in a simulation activity is typed as *artificial* or *natural* (Alessi & Trollip, 2001). Artificial feedback involves the instructor or the instructional system (for example, computer-based simulation) correcting the learner during the simulation when he or she makes an incorrect decision or takes an inappropriate action. Artificial feedback is preferable early in learning to avoid reinforcing undesirable behavior. In a natural feedback condition, which is appropriate for applying or assessing skill learning, feedback is delayed and the learner will not become aware of an incorrect decision or action until the simulated patient dies or the airplane runs out of fuel mid-flight.

Principle 5: Artificial Simulation Feedback Early in Learning; Natural Simulation Feedback in Later Practice

Technology-Based Augmented Feedback. Augmented feedback is artificial, such as the score given for a successful skill execution or the verbal comments of a coach. Augmented feedback can be immediate or delayed. Generally, newer learners benefit more from immediate augmented (also called extrinsic) feedback provided during practice while experienced learners, who are often highly aware of their own performance from the inherent feedback they receive from their own bodies, can find immediate augmented feedback to be distracting or confusing.

Technology provides a key type of delayed augmented feedback. Video, and before that film, have been extraordinarily valuable learning tools for performers of complex psychomotor skills in a range of domains, from sports to surgery. Affordable video analysis tools are now available to teachers, trainers, and coaches that allow one performance by a learner to be compared side-by-side with or overlaid on another performance by the same learner or by a model performer (Dartfish, 2008). Video analysis tools allow portions of a videotaped performance to be coded and compiled so that, for example, a wrestler and his coach can study all of his takedowns—and his opponents' takedowns of him. For logistical as well as instructional reasons, technology-based augmented feedback is almost always delayed—which is considered to be less beneficial to learners just developing new psychomotor skills but more beneficial to advanced learners, who are able to recall their earlier performance and process a coach's retrospective feedback or their own observations.

Principle 6: Constant Augmented Feedback for Initial Learning; Delayed Augmented Feedback (Such as Video) with More Advanced Learners

Questioning and Self-Regulation. As performers advance to levels of expertise or near expertise in a performance domain, the role of formal and systematic training becomes less clear. While top athletes continue to practice the subskills of their craft on a daily basis, including receiving direction and motivation from a professional coach, most professions and skilled crafts do not have a culture of practice that includes direction and regular feedback from a coach. Performers become largely responsible for their own progression as performers. Within this progression, however, a trainer or mentor may have an opportunity to help the performer progress by using the activity of *questioning*. That is, the trainer or mentor asks questions of a performer that lead the performer to reflect critically on his or her performance. Questioning can be a step toward the performer developing the type of self-regulation and self-coaching that typify expert performers in a wide range of domains. The goal of questioning is that advancing learners progress along a path of decreasing dependence on a coach or trainer and increasing self-awareness and self-control (Vickers, 2007).

Principle 7: Questioning to Help Advancing Learners Develop Self-Coaching

Part-Task Versus Whole-Task Practice. One of the key design considerations in the training of psychomotor performance skills is whether to take a *part-task* or a *whole-task* approach to practice. The emphasis of modern instructional design and learning theory, as well as coaching theory, is in the direction of involving contextual, whole-task practice earlier and more often during instruction (Merrill, 2002; Vickers, 2007). The problem with whole-task practice such as sports scrimmages, war gaming, and simulator training is that it can be expensive. Whole-task activities, which are almost by definition contextual and experiential, tend to be instructionally inefficient in comparison to part-task methods such as drill-and-practice (Alessi & Trollip, 2001).

While experiential, whole-task learning has clear benefits for transfer of learning to performance, there are also benefits to conducting part-task, drill type training—not only of the motor production component (as is typically done) but also of the *recognition* component. The part-task recognition training approach is based on sports expertise research that has revealed recognition skills as differentiating expert performers in many reactive sports skills. Sport expertise research has further shown that such recognition skills are eminently trainable using techniques derived from expert-novice studies, most notably the method of video-simulation (Ward, Williams, & Hancock, 2006).

Principle 8: Part-Task Drills to Train Recognition Skills Separate from Motor Skills

Later in the chapter, I summarize the sports expertise research that establishes a foundation for the part-task approach to training of recognition skills using video-simulation along with emerging research that extends the approach beyond sports. Following the research review, I unfold a hypothetical example that describes the design of a program to train veteran truck drivers in the complex psychomotor performance of backing a fifty-three-foot trailer into a loading dock while avoiding often unseen and sometimes moving obstacles. The design of the truck-backing training program incorporates traditional part-task training of the motor production aspects of the skill as well as innovative part-task training activities that target the recognition aspects of this complex psychomotor performance skill.

GUIDELINES FOR TRAINING PSYCHOMOTOR PERFORMANCE SKILLS

Before moving to the review of sports expertise research and the design of the truck-backing training program, I offer the following set of guidelines for designing a particular type of psychomotor training that is common in corporate, military, and higher-education settings. That is, training adult, pre-service or in-service professionals in highly procedural psychomotor skills within a group workshop setting. These guidelines, which are based on the *2002 National Guidelines for Educating Emergency Medical Services (EMS) Instructors* (NHTSA, n.d.), relate to a non-sports psychomotor performance context that also involves rapid decisions and actions. The *EMS* guidelines have been adapted to include established and emerging instructional design principles and include recommendations related to five aspects of designing a psychomotor training program: levels of psychomotor performance, demonstrating psychomotor skills, practicing psychomotor skills, feedback during practice, and group training.

Levels of Psychomotor Performance

1. Imitation
   a. Trainee repeats what the instructor does: "See one, do one."
   b. Avoid modeling incorrect behaviors because trainees will do as you do.
   c. Some skills are learned entirely by observation; no need for formal instruction.
2. Manipulation
   a. Provide guidelines as a foundation for learning new procedures (skill sheets).
   b. Use forward or backward chaining of component sub-skills to build a sequence.
   c. Use blocked practice for rapid learning of newly acquired sub-skills.
   d. Interrupt and correct incorrect behavior in beginners.
3. Precision
   a. Trainees practice sufficiently to produce skill without mistakes.
   b. Trainees can perform the skill in a limited setting only. Shape behavior through increasingly challenging settings.
   c. Allow advanced trainees to identify and correct their own mistakes. Involves trainees visualizing themselves performing the skills.
   d. Let trainees develop their own style within acceptable behaviors.
4. Articulation
   a. Trainees explain why the skill is done a certain way.
   b. Trainees describe what adjustments can be made to skill sequence and when.
   c. Trainees recognize and self-correct errors.
5. Naturalization
   a. Trainees perform basic skills accurately, quickly, and with low cognitive effort.
   b. Trainees multi-task effectively by minimizing cognitive load on routine motor tasks, thus freeing mental resources for more complex cognitive tasks.
   c. Trainees perform skills confidently and competently in a variety of scenarios.

Demonstrating Psychomotor Performance Skills

1. Whole-part-whole demonstration of skills.

   a. Instructor introduces the skill by demonstrating the entire skill from beginning to end while briefly naming each section.
   b. Instructor demonstrates the skill sequence again, explaining each step in detail. Trainees may interject questions during the step-by-step demonstration.
   c. Instructor models the entire skill sequence by performing it in real time without interruption or commentary.
2. Whole-part-whole provides trainees with multiple observation opportunities.
3. Whole-part-whole appeals to both analytic learners who prefer step-by-step description and global learners who prefer an overview.

Practice of Psychomotor Performance Skills

1. After demonstration of skill sequence, trainees practice sub-skills using checklist.
2. Trainees memorize the steps of the skill until they can verbalize the sequence.
3. Trainees perform the sequence stating each step as they perform it (no checklist).
4. Trainees perform the sequence while answering questions about their performance in order to increase meta-cognitive awareness.
5. Trainees should be allowed to progress at their own pace. The need for direct supervision should lessen as trainees' skills increase.
6. When ready, trainees perform the skills in context of scenarios or simulations.
7. Trainees should be allowed ample time to practice before being tested.

Feedback During Psychomotor Skill Practice

1. Interrupt and correct incorrect or inappropriate behavior in beginners.
2. Practice sessions should end on a correct performance or demonstration of the skill.
3. Under limited supervision, allow advanced trainees to identify mistakes and make corrective adjustments in themselves and others (delayed feedback).
4. Provide trainees with positive feedback to reinforce correct behaviors.
5. Allow adults to develop their own style after mastery has been achieved. Focus on acceptable behaviors instead of rote performance.

Situated Skill Learning in Group Training Sessions

1. Assign students in each group to roles (depending on size of group) during scenarios and simulations, including:
   a. Evaluator. Uses a skill sheet, videotape, or audiotape to create a record. Multiple students can evaluate and compare observations.
   b. Information provider. Uses script to "run" scenario.
   c. Team leader. The primary decision-maker of the group.
   d. Partner or assistant. Gathers information to inform decisions.
   e. Patient, customer, or other central person in scenario. Portrays symptoms or behaviors according to role in scenario.
   f. Bystanders. Can depict helpful or distracting roles.
2. Instructor should not interrupt the scenario, except for safety concerns, but rather make notes for debriefing session to follow scenario.
3. Instructor provides group performance evaluation in debrief session.
   a. Use positive-negative-positive format when possible.
   b. Provide constructive criticism and areas for improvement.
   c. End with reinforcement of critical aspects of skill performance.
   d. Participants comment from the perspective of their roles.
4. Rotate roles for next scenario or simulation.

This list of guidelines is adapted from the *2002 National Guidelines for Educating EMS Instructors* (NHTSA, n.d.). Burke (1989), Kolb (1984), Millis and Costello (1998), and Watson (1980) were cited as sources in the original U.S. government document. These guidelines are specific to training a particular type of learners (adult, professional) in particular types of psychomotor performance skills (procedural, adaptive) in a particular training context (workshop). When similar skills, for example cardiopulmonary resuscitation (CPR), are taught to different learners in different contexts and with different goals, then different guidelines might apply.

The sports-based principles for training psychomotor performance skills and the EMS-based guidelines for workshop-style psychomotor training serve as a summary of current theory and practice in psychomotor training. The following sections explore an emerging part-task approach to training complex psychomotor performance skills that addresses motor production skills and recognition skills separately with targeted, optimized, and therefore instructionally efficient training activities. While still based in sports science, the foundational research has been conducted not in the area of kinesiology that has generated motor skill training principles but rather in an area of sports psychology that pursues *sports expertise* research.

SPORTS EXPERTISE RESEARCH

While sports scientists in the kinesiology area have traditionally focused on the production of motor skills, a group of sports expertise researchers in the sport psychology area have focused on decision making in *open* sports such as tennis, basketball, soccer, and hockey, rather than on skill production in *closed* sports such as golf and gymnastics. As shown in Table 14.1, closed sports are primarily concerned with the consistent execution of motor actions while open sports involve dynamically adapting actions to changing conditions, especially the actions of an opponent. This chapter extends this focus on open rather than closed skills to other domains of psychomotor performance.

The focus of sports expertise researchers on the recognition component of psychomotor skills goes back to the early 1980s and is based in general theories of expertise and expert performance that are rooted in classic chess research. Studies of expert and novice (less expert) chess players revealed that the experts enjoyed a software advantage in the form of chess-specific schema rather than a hardware advantage such as prodigious memory (Simon & Chase, 1973). In classic experiments, it was shown that expert chess players were not substantially better than less expert players at arranging chess pieces on a blank board to replicate the arbitrary arrangement of pieces on a board that they viewed for only a short time. However, when the stimulus chessboard had a meaningful arrangement of pieces from an actual game, then the experts were much better at replicating the arrangement. The researchers inferred that the expert chess players were able to encode information into chunks that could be more easily remembered and then decoded, thereby circumventing the limitations of working memory.

The classic chess experiments generated a distinct approach to the study of expertise and expert performance that has been modeled and researched in performance domains ranging from aviation to physics problem solving and including sports performance (Ericsson, Charness, Feltovich, & Hoffman, 2006).

Table 14.1 Open Versus Closed Psychomotor Performance Skills

	Open Skills	*Closed Skills*
Sports	Tennis, basketball, soccer	Golf, gymnastics, bowling
Other domains	Vehicle operation, surgery	Product assembly
Performance goal	React to opponent or environment by adjusting motor sequence	Reproduce motor sequence accurately

Sports scientists working within the expert-novice paradigm of expertise research have shown that the seat of expertise in reactive sports skills such as blocking shots on goal in hockey and soccer or batting a ball in baseball and cricket lies in the experts' ability to "read" an opponent's actions and anticipate the outcome more than in the production of motor actions. That is not to say that motor actions are not important but rather that production skills don't *differentiate* expert from less expert performers. Whether baseball batters or vascular surgeons, performers need to have mastered requisite production skills to be "in the game."

From a training perspective, the key question is whether the recognition skills that differentiate expert performers can be systematically improved through training activities. That question has been addressed by sports expertise researchers who have developed and implemented training programs that essentially repurpose the tasks used to measure expert recognition skills into training tasks to target and improve those same recognition skills. Most of these recognition training studies have targeted the ballistic and reactive skills of returning serve in tennis (Farrow, Chivers, Hardingham, & Sasche, 1998; Haskins, 1965; Scott, Scott, & Howe, 1998; Singer, Cauraugh, Chen, Steinberg, Frehlich, & Wang, 1994) and batting in baseball (Burroughs, 1984; Fadde, 2006). All of these training programs used the *video-simulation* method developed for expertise research studies in which participants view and react to a video or film display of an opponent's action (serve or pitch).

In most of the reported recognition training studies, video-simulation training of recognition skills was associated with improved performance of the full skill in either live performance-based tasks (near transfer) or in laboratory-based simulations (Williams & Ward, 2003). At least one study produced far transfer of recognition training to full-context performance. In that study, college baseball players who received ten fifteen-minute pitch recognition training sessions performed better than a control group of players from the same team in game batting performance as measured by official National Collegiate Athletic Association (NCAA) batting statistics (Fadde, 2006).

The baseball pitch recognition training program (Fadde, 2006) illustrates the close link that can be made between experimental research and skill training, not only in application of theory and findings but also adoption of research methods such as video-simulation. Video simulation involves research participants or trainees viewing a visual depiction of an opponent's action, in this case delivering a pitch, and then identifying the type of pitch or predicting the location of the pitch in the strike zone. The visual display is edited to black (temporal occlusion) at various points in the pitcher's delivery and resulting ball flight. For research purposes, the ability of more expert and less expert batters was compared at various occlusion points. An expert-novice study by Paull and Glencross (1997) found that novices performed as well as experts when more than one-third of ball flight was shown. On the other end, the performance of both experts and novices was reduced to chance at occlusion points before the moment-of-release of the pitch. The window of expert advantage, then, is between release of the pitch and one-third of ball flight. Fadde (2006) repurposed the research design as a training design by arranging stimulus video of pitches in a sequence of progressive difficulty that started by showing trainees video clips with about one-third of ball flight shown and progressing, with mastery, through clips showing less ball flight and ultimately to clips occluded at the point-of-release of the pitch.

Few psychomotor performance skills, in sports or other domains, are as ballistic as returning a 120-mile-per-hour serve or hitting a ninety-mile-per-hour pitch. However, if the recognition-action link, which appears to be inextricably linked in these skills, can be de-coupled for targeted training and then re-coupled to improve performance, then that argues convincingly for applying the approach in other, less ballistic, psychomotor performance domains. Indeed, the case has been made for applying part-task recognition training approaches in areas of performance well beyond those typically associated with psychomotor skills, such as classroom management and radiology (Fadde, 2007).

There are two key implications of part-task training of recognition skills as a component of psychomotor performance. The first is that, since recognition skills have not been systematically addressed in training in the same way that production skills have been, there is an opportunity to improve on the proven methods of psychomotor training. The other implication is that part-task training of recognition skills, separate from production skills, can be delivered much less expensively than full-task training that often involves high-fidelity simulations. In the hypothetical example of training tractor-trailer drivers to back their rigs that is elaborated later in this chapter, that means that the recognition component of this complex psychomotor performance can be trained over the Internet. Of course, drivers still need to train production skills by backing up real trucks in controlled conditions. Ultimately, the production and recognition components are re-coupled to facilitate and assess transfer of learning to real-world performance.

TRAINING THE RECOGNITION COMPONENT OF PSYCHOMOTOR SKILLS

Figure 14.1 depicts a college softball player engaging in part-task, motor skill practice. The coach leads the batter through a sequence of batting drills that emphasize different parts of her swing, a typical approach to the development of

Figure 14.1 Softball Batting Practice.

complex psychomotor skills in sports. This part-task coaching approach uses the behavioral principle of *chaining* to break the batter's swing down into component segments, targeting each segment with specific drills, and then recombining the component skills to form a cohesive full-skill. The coach then uses the behavioral principle of *shaping* to add context and degrees of difficulty in moving batting practice training tasks closer to game performance.

Figure 14.2 shows a softball player engaged in a computer drill that focuses on the recognition component of the complex psychomotor skill of softball batting. Working entirely in the cognitive domain, the computer program quizzes the player on the type or location of a pitch thrown by the pitcher shown on the video screen. The design of the computer-based pitch recognition training program (*Interactive Video Training of Perceptual Decision Making*, 2007) is based on expert-novice research in sports science in which a sizable body of research has isolated early recognition and anticipation skills as the "seat of expertise" in many sports skills that involve rapid decision making and actions.

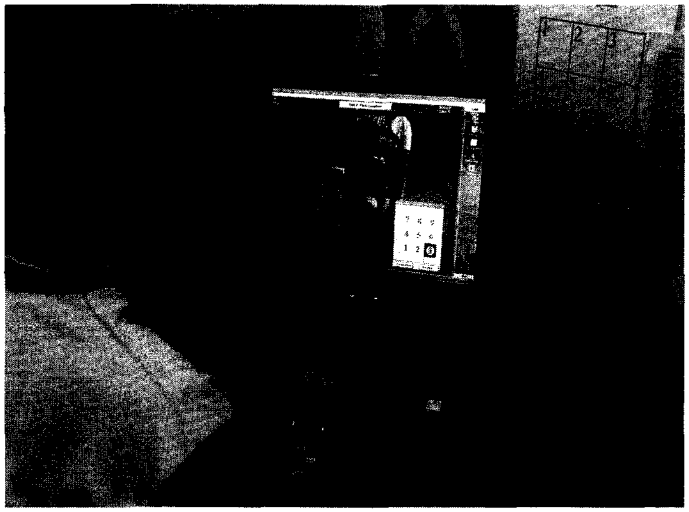

Figure 14.2 Pitch Recognition Training (Video Simulation).

Not only has sports expertise research provided a theoretical foundation and empirical findings to support training skills, but it has also provided model tasks that were designed to measure skills but that are readily repurposed for training skills. This is an equally important contribution as the skills that are being considered here have not traditionally been part of systematic coaching or training designs. As can be seen in Figure 14.2, *video-simulation* training involves learners viewing a video display that depicts the point of view (POV) of a live participant. The participant then engages in drills that require recognizing the type of pitch being thrown or predicting the location of the pitch in the hitting zone. Improving the pitch recognition component of batting, separate from physical batting actions, can lead to improved performance by batters who already possess requisite physical and technical batting skills. There is reason to believe that a video-simulation approach targeting recognition components can also lead to improved performance in a wide range of non-sports psychomotor skills.

BACK TO THE FUTURE: DESIGNING A PART-TASK PSYCHOMOTOR PERFORMANCE SKILLS TRAINING PROGRAM

The principles and guidelines offered earlier in the chapter, along with the recognition training approach described above, are integrated through a hypothetical scenario addressing the design and development of a training program,

called *Back to the Future*, that is intended to improve the backing skills of veteran over-the-road truck drivers. *Back to the Future* demonstrates the benefits in terms of instructional effectiveness and efficiency that the part-task production/recognition approach brings to training complex psychomotor performance skills.

In this scenario, instructional design consultants from Human Performance and Learning Corporation (HPLC) design a training program for the mid-size national transportation firm PJF Fleet. The scenario reflects a typical but challenging training context in which the trainees are already advanced performers—although lacking in a newly emphasized skill set. As the instructional design consultants face an array of design decisions, they apply instructional design theory, research, and principles such as those provided in this chapter and also elsewhere in this volume. As the real world intrudes upon pure design, the consultants must also consider the client's priorities, deadlines, and resources.

Scenario: *Back to the Future* Truck Driver Training Program

PJF Fleet, a national trucking firm, has recently expanded its business into offering dedicated account service (DAS). DAS accounts essentially use PJF Fleet trucks and drivers as their own contracted fleet. PJF Fleet's training problem is that many potential DAS clients require deliveries in urban areas, a type of driving that is unfamiliar to most PJF Fleet drivers, since the company had been strictly an over-the-road carrier. Even some of the firm's "million-milers" (drivers who have logged over one million highway miles without accident or incident) have very limited experience driving a tractor-trailer in urban environments. The greatest area of concern to the firm, to clients, and to drivers themselves involves backing forty-eight-foot and fifty-three-foot trailers into loading docks located in congested urban areas. The firm has contracted Human Performance and Learning Consultants (HPLC) to create a training program to, in the words of the company's human resources director, "teach our drivers how to drive backwards."

Domain of Learning. The first thing that HPLC does is to determine what domains of learning are involved in the training project, since different domains (affective, cognitive, psychomotor) call for different training strategies. Obviously, the target skill involves complex physical movements and is therefore in the psychomotor domain. Backing tractor-trailers in urban areas also involves problem solving and planning, so there is a cognitive aspect. The cognitive aspect includes both *declarative knowledge* of company policies and applicable traffic laws and *procedural knowledge* of proper backing techniques. With any in-service training program that is required, there is also an affective aspect that can impact the motivation of the learners. However, PJF Fleet has assured HPLC that the training will not be required, but rather that new DAS accounts will be among the highest paying for drivers and will allow drivers to drive in a geographically limited region rather than cross-country. They expect that drivers will vie for the new accounts. PJF Fleet does want to assure DAS clients that their drivers are certifiably skilled at the type of driving—or in this case, backing—that DAS accounts for. PJF Fleet will require that drivers take and pass the backing program (the first of a probable series of urban driving training programs), but only if the drivers want to be considered for DAS accounts.

HPLC first looks at the declarative knowledge aspect of the training. However, an interview with the PJF Fleet driver/instructor who had been assigned to act as subject-matter expert (SME) suggests that the information to be learned—including policies, laws, and "official" techniques related to backing procedures—is not overly detailed or challenging to learn. The challenge, the SME insists, is lack of experience. With lack of experience comes lack of confidence. And, as the SME points out, maneuvering a fifty-three-foot trailer into a docking position while blocking multiple lanes of traffic cannot be done tentatively.

When interviewed about the kind of knowledge that a driver needs to have in order to successfully perform backing maneuvers, as opposed to pass a paper test, the SME immediately lists an array of tips that drivers use—most of which have not appeared in the technical literature and some of which contradict official policy and techniques. For example, the PJF Fleet policy requires that drivers conduct a GOAL (Get Out And Look) at least once during *every* backing maneuver and at any point in the maneuver when the driver is unsure of the location of the trailer. "But if you did that," notes the SME, "you'd never get the job done. Cars start honking and trying to get around you, and pretty soon a cop is there saying 'Driver, you've got to move this rig NOW.' And they don't take any 'yeah, buts.' So then you're calling the dispatcher and saying you can't make the delivery. That's actually what the policy says to do. But that's going to make a p.o.'d customer and make the driver look bad."

Declarative knowledge, then, turns out to be less of a learning issue than is *procedural knowledge*—that is, knowledge that influences action. HPLC needs to figure out how to extract the real knowledge that drivers have. They also need to determine what the client's *real* goals are for the training program: do they want printed policies reinforced more than they want success in urban environments?

Training Goals. HPLC has considerable experience with designing certification training programs and immediately recognizes the need to clarify the underlying goals of the training program with PJF Fleet. Simply put, HPLC needs to know whether the training is actually intended to improve performance or if it is "check off" training intended to certify that employees had been given required information. PJF Fleet's vice president for safety and operations assures the consultants that this training program is indeed intended to improve performance. When presented with the SME's initial list of truck backing tips, the V.P.—who had been a driver for twenty years—laughs and says, "Yeah, that's the real stuff." HPLC is now emboldened to conduct a *cognitive task analysis* (see Chapter Seven of this volume) in order to determine what experienced drivers actually *think and do* in order to plan and execute successful backing maneuvers in difficult situations.

Cognitive Task Analysis. Before conducting cognitive task analysis (CTA), HPLC consultants check industry and academic literatures looking for research or recommendations concerning backing tractor-trailers. Although they find numerous prescriptive guidelines, they do not locate information on how expert drivers actually perform maneuvers or on the performance problems that less skilled drivers have with such maneuvers. HPLC therefore conducts its own version of an expert-novice research study for the purposes of discovering what expert drivers do and think while performing, especially what they do and think that is different from less expert drivers.

HPLC recruits three representative PJF Fleet drivers who have considerable experience with over-the-road driving but little experience with local (that is, urban) driving and therefore with difficult backing situations. HPLC also recruits three independent drivers who routinely make local deliveries using "sleeper cab" tractors, which have a compartment behind the driver and passenger seats that serves as a sleeping room for over-the-road drivers. Most local service deliveries are made using "day cab" tractors, which have a back window behind the driver rather than a sleeping compartment. Day cabs are much easier to back because drivers can turn and get a "visual" (direct rather than mirror view) out of the back window. Backing using a sleeper cab allows the driver to get a turn-and-look visual out of the driver-side window but requires relying on the passenger-side mirror—which can result in a "blind" back. Simply, sleeper cab tractors are not designed for precise backing. However, the value-added proposition of PJF Fleet's new DAS service is that the same trucks that have transported the client's goods over-the-road will make the local delivery, without an interim stage of redistributing goods for local delivery.

Three PJF Fleet drivers and the three "expert" drivers participate in a series of representative backing maneuvers at PJF Fleet's closed-course training facility. HPLC measures the drivers' performance in terms of the speed and accuracy with which the maneuvers are executed. HPLC also videotapes each trial and then conducts *retrospective think-aloud protocol* in which the drivers talk through their cognitive and psychomotor processes while reviewing the video ("I'm trying to feel my perimeters. Feels like about two feet of clearance on the blind side. Should be able to cut the wheels . . . but getting nervous. OK, now I need to get out and check"). HPLC pays particular attention to when drivers stopped for a GOAL, sometimes rewinding the tape and asking the driver where he thought the trailer was in relation to obstacles set up on the closed-course.

HPLC's form of cognitive task analysis reveals critical differences between expert and representative (less expert) drivers in two areas: (1) maneuvering the forty-eight-foot and fifty-three-foot trailers precisely and confidently and (2) accurately estimating the proximity of the perimeters of their tractor and trailer to obstacles.

Instructional Goals. Based on the CTA, HPLC decides to address two key elements of backing in the training program, which they title: *Trust Your Mirrors* and *Steer Your Rig*. Within the psychomotor performance of backing, *Steer* addresses production skills and *Mirrors* addresses recognition skills. Identifying production and recognition as separate components has important implications for how the training modules can and should be delivered. HPLC presents and gains approval from the client for a program that by now has picked up the name *Back to the Future* (the client suggested the name as evoking the new opportunities represented by DAS accounts).

After the CTA, HPLC and the SME are able to create a set of representative backing tasks, including sighted-straight-line back, blind-side straight-line back, sighted jack-knife back, and blind-side jack-knife back. They also generate preliminary criteria for the speed as well as accuracy that would represent *mastery* of the backing tasks. Having determined the instructional objectives, the next step is to ascertain the current level of skill of the target learners and thereby determine the *performance gap*—not of individual learners (that would be determined in a pre-test stage of training) but rather of the group as a guide to creating training content.

Learner Profile. HPLC now reviews the work experience of a representative sampling of PJF Fleet drivers who have indicated an interest in DAS and finds that they vary considerably in the amount of urban driving experience that they have logged. Ironically, some of the newer drivers coming from other jobs or recent truck driver training programs have more experience and some of the veteran drivers are the least experienced. Earlier the SME had noted that many of the veteran drivers have a great deal of pride and are likely to be resistant to any kind of "training" program. Indeed, drivers (and practicing professionals of all types) often express disdain for training programs.

In part to demonstrate the value of training to drivers, HPLC decides to develop a performance-based *pre-test*. If drivers pass an in-truck performance test, then they will get full credit for the *Steering* component of the training program. The test-out procedure will also serve as a pre-test for the learners who do not pass the test and should convince trainees of their need for the training program as well as provide trainers with a profile of each individual trainee's performance gap.

Training Resources and Constraints. PJF Fleet will be fully compensating drivers for missed driving time in addition to paying travel, housing, and per diem costs. A primary constraint for HPLC, then, is to minimize on-site training. Resources available at the PJF Fleet training facility include one permanently installed simulator along with a portable simulator that can be scheduled into the training facility. PJF Fleet's internal training department assures HPLC that the simulators can be programmed to present backing scenarios and estimates that they could generate scenarios, including graphics representing urban obstacles, for a cost of approximately $2,000 each. The closed driving course can also be set up with simulated backing environments that could include overhead obstacles such as power lines in addition to the usual parked cars, trees, and fire hydrants. The PJF Fleet training department estimates that they could arrange a variety of closed-course backing environments for a cost of $1,000 each, which includes hiring local high school students to set up cones and obstacles on the closed-course during training sessions.

Although the availability of the simulators is tempting, HPLC opts for in-cab, closed-course training for the *Steer Your Rig* motor component of the *Back to the Future* program. There are several reasons. The first is that learners are generally more satisfied with "live" training using authentic equipment than they are with simulators. In addition, the SME suggested that PJF Fleet drivers associated the simulators with "punishment" training that was required after any moving vehicle incident.

A subtler factor is that, because the recognition component of the training program will be addressing contextual problem-solving aspects of performance, it would be acceptable to focus the motor training part of the program on developing motor skills in an essentially context-free environment (for a full discussion of highly engaging learning environments, see Chapter Twelve in this volume). One of the benefits to the part-task psychomotor training approach separating the production and recognition components of performance is that each mode can then be optimized—usually resulting in both subtask learning environments being less expensive *and* more effective than whole-skill simulation—whether live or simulator based.

HPLC now has enough knowledge of the instructional goals, the learner profile, and the client's resources and constraints to create an initial design for the *Back to the Future* training program. They focus first on the more conventional motor skill component of the training program.

Stages of Instruction

Adapting Alessi and Trollip's (2001) stages of instruction, HPLC addresses the following stages of instruction:

Assessment (pre-test)

Instruction

Practice/Application

Assessment (certification test)

These stages apply to single instructional offerings, such as a workshop, in addition to complete programs of instruction. The key consideration for HPLC in designing the *Back to the Future* training program is to determine which stages of instruction require bringing learners to the central training facility and which stages of instruction can be completed without drivers coming in from the road. HPLC has much more flexibility in designating the delivery mode for the various stages of instruction because they conceive of production skills and recognition skills as separate components of the performance and of the training program. The stages of instruction that HPLC addresses are:

Assessment (Pre-Test). The pre-test assessment will serve two instructional purposes; one is that it will reveal the level of existing skill that drivers have, which PJF Fleet trainers can use to adapt the instruction materials and activities to the learning needs of the group and of individual drivers. Some drivers may need pre-training remediation and others may pass out of the *Steer* portion of the training program. Drivers who pass out of the *Steer* module will still need to complete other training activities involving declarative knowledge of legal and policy information and the *Mirrors* recognition training module, and will have to pass the non-driving parts of the certification test.

The other purpose of the skills pre-test is to demonstrate to the learners that the desired level of backing skill is not perfunctory. The pre-test should be demanding so that any drivers who pass out of the module have clearly demonstrated superior backing skills. The demanding pre-test provides a target level of mastery that learners know they will work toward achieving and should convince them that they need the training (affective objective). The pre-test will be conducted on the closed-course range and involve a variety of backing tasks: straight line, jack knife, sighted and blind side, and with stationary obstacles and moving obstacles—with each maneuver scored in terms of speed as well as accuracy. The pre-test will be given before training to drivers who wish to test out, and then will be given at the outset of training to all remaining trainees.

Instruction. Instruction in psychomotor skills typically comes in the form of demonstration and modeling. The *National Guidelines for Educating EMS Instructors* (NHTSA, n.d.) suggests taking a *whole-part-whole* approach to demonstrating psychomotor procedures. That entails the instructor demonstrating the whole process from beginning to end, naming each component step. The instructor then goes through the process again, step-by-step, offering expert "tips" and answering questions from trainees. The instructor then demonstrates the whole process in real time without taking questions or making observations.

One of the *guidelines* is to have a credible model demonstrate the skills, whether that demonstration is live or in a mediated form. For the *Back to the Future* training program, HPLC decides to produce a series of videos demonstrating the techniques and procedures to be used in the various truck backing situations. By producing videos rather than having live demonstration, HPLC can control the accuracy and consistency of the demonstrations, which can have legal as well as instructional value.

HPLC also decides to use the SME to provide narration to accompany video of an expert driver executing the required maneuvers. The SME will ride in the passenger seat of the truck cab, describing each step that the driver takes in the first stage of the whole-part-whole demonstration of each maneuver and then asking the driver questions in the middle part of the demonstration. HPLC also creates a checklist of tips and procedures for each of the common backing situations. These can be kept by the trainees to use as job aids during *Back to the Future* practice and testing activities and later for continued use in the field.

HPLC plans to have trainees watch the demonstration videos on a portable DVD player in their truck cabs while sitting on the closed-course, and then transition directly into guided practice activities. HPLC provides a portable DVD player to each trainee with the instructional truck backing videos compiled on a disc. The trainees will be allowed to keep the portable DVD player (bulk cost: $70 each) if they successfully complete the on-site portion of the *Back to the Future* program. A PJF Fleet executive has suggested including a DVD of the Michael Fox comedy movie classic and, although there is no research or theory basis for doing so, HPLC embraces PJF Fleet's "branding" of the training program as a way to address the affective objective of having drivers accept and value the training program.

Consistent with recommendations emerging from research in cognitive as well as psychomotor learning, HPLC directs the SME to deliver externally focused implicit instruction (results oriented) rather than internally focused instruction (technique oriented). In other words, describe what the tractor or the trailer needed to be doing at a particular point in a backing procedure rather than providing step-by-step instruction in how to execute the maneuver.

Practice. Guided practice is the most important element of mastering psychomotor skills. As noted in the *Guidelines* discussion, practice can be optimized for rapid initial learning or for retention and transfer. For the *Back to the Future* training program, the emphasis is clearly on transfer of learning to performance. Further, HPLC is dealing with motivated and "captive" learners in that drivers are required to pass (or pass out of) the training in order to be considered for the DAS accounts for which they have applied.

Part-Task Versus Whole-Task Practice. Referring back to the earlier section discussing *Guidelines* for psychomotor performance training, the optimal design of practice would seem to be variable, spaced, whole-skill and smart practice of the sort described by Vickers (2007) as decision training. After conducting the cognitive task analysis (CTA), though, it had become clear that in this situation there is little need to train PJF Fleet drivers in the component motor sub-skills involved in maneuvering a tractor and trailer. As the SME put it, "They know how to work their rig." So the behavioral training strategy of chaining component sub-skills is not relevant. *Shaping*, however, is a basic motor learning strategy to be considered along with the alternative *hard first* approach—which, as noted earlier, might better be termed *hard from the start*. In this case, HPLC identifies four distinct types of backing maneuvers to be trained: sighted straight line, sighted jack knife, blind-side straight line, and blind-side jack knife (the ultimate challenge of tractor-trailer backing). Additionally, testing and/or practice tasks have been envisioned in which moving obstacles and limited time frames are added in each of the four basic maneuvers in order to increase difficulty and realism.

Shaping in this case refers to the individual backing maneuvers. For example, shaping of the blind-side straight-line back would involve creating a simplified version of the maneuver on the closed course, perhaps with orange cones marking the target. As a driver/trainee masters the simplified version of the blind-side straight-line back, he or she progresses to more challenging and contextual versions (for instance, with a wooden construction representing a dock) of the same maneuver. Hard first practice suggests bypassing a simplified version of the task and jumping right into a more representative version of the task. A logistic advantage of the hard first approach is that the course would not have to be constantly re-set to depict progressively more difficult versions of each task. HPLC designed a shaping approach in which repeated trials on each basic maneuver would remain essentially the same but would have progressive difficulty, a key element of drill-type practice, introduced through adding time limits and physical obstacles in later trials.

Practice Scheduling. HPLC had first considered an optimal design of backing practice that would be *variable* and *spaced*. That is, trainees would make a blind-side straight-line back followed by a sighted jack-knife back and so on, in no particular order. In addition, relatively short practice sessions would be spread out over several training sessions. However, in one of those instances of logistical real-world considerations overriding optimal instructional design decisions, HPLC was told that (1) they could not have workers running around re-setting the closed course for every trial by every driver and (2) they had to minimize the number of days that drivers were off the road.

Ultimately, the four backing tasks, and the time-pressured condition for each one, are designed to be conducted in blocks. A natural progression is built into the practice activities by starting with the sighted straight-line task that was easy for almost any experienced driver, then moving to the blind-side straight-line back, the sighted jack-knife back, and finally the notorious blind-side jack-knife back. HPLC agrees to the client's goal of training up to ten drivers per training session.

Feedback and Guidance During Practice. Traditional models of sports coaching and other types of motor instruction typically involve the teacher, trainer, or coach providing concurrent, intrinsically focused (technique) feedback during practice trials. Generally, less skilled learners benefit from such *knowledge-of-performance* feedback, while more skilled learners benefit more from delayed *knowledge-of-results* feedback. With the PJF Fleet drivers being highly skilled in the performance domain of truck driving, if not yet in the targeted psychomotor skills of truck backing, recognizing that accomplished performers often have individual styles rather than insisting on rote display of techniques should help to cultivate a positive training environment.

The SME asked HPLC to consider a favorite technique for providing feedback during practice in which he stands on the step right outside the driver's window while the truck is in motion, literally getting in the driver's ear with running instructions, tips, feedback, and encouragement. The SME had used the technique previously in teaching novice drivers how to execute blind-side backs and reported that the technique was both effective and popular with drivers. However, HPLC's emerging training design includes multiple trainers working with up to ten drivers on the closed course at one time. Although the "in your ear" method fits the mode of constant augmented feedback that can be effective for initial skill learning, the method does not scale up well.

HPLC also has concerns that concurrent, augmented feedback—while appropriate for novice learners—might override the intrinsic feedback that drivers need to develop to be their "own coaches" in the field. Instead, HPLC settles on delayed augmented feedback in which every trainee's practice maneuver will be videotaped, with the video being recorded by a computer with video analysis software. The trainees who are on the course at the same time will be split into two groups. One will be executing maneuvers with tractor-trailers on the course and the other group will be reviewing the videos of their practice trials with the video-trainer. The groups then change positions and trainers for the next trial.

Test-Instruction-Practice Integration. The training tasks designed to develop the motor component of the truck-backing skills are essentially an extension of the pre-test tasks: sighted straight line, blind-side straight line, sighted jack knife, and blind-side jack knife with a time-pressured version of each added. In conjunction with PJF Fleet's internal training department, HPLC designs the pre-testing stage to transition into the instructional stage and then into the structured practice stage—all to be accomplished in a three-hour time block. They will "own" the closed course for the duration of the *Back to the Future* project. Ten drivers will be trained in a morning session and ten more in an afternoon session (minimizing housing costs and drivers' time off the road) until every driver who has applied for a DAS account has been trained. The training will involve five trucks and five drivers working with two trainers, an on-course trainer, and a video-review trainer. PJF Fleet will further hire temporary help to rearrange the cones and barriers that define each different backing task. While the cones and barriers are being reset, the drivers will watch the seven-minute demonstration video that goes with the next backing task. The drivers will perform the four backing tasks in blocks of thirty minutes each, with ten minutes of set-up time before each block of practice.

Watching the demonstration videos between blocks of backing practice is intended to provide a degree of *spaced practice*, which is considered to facilitate transfer of training to performance. The workers slightly rearrange the cones between trials to add a degree of *variability* within the single-task, blocked practice. The time-pressure condition is added in the final ten minutes of each block, which further adds a degree of *progressive difficulty*.

Ultimately, the blocked, single-session practice schedule is not optimal for transfer of learning to performance. HPLC would have liked to space practice over several sessions, perhaps covering a training period of several weeks, with the intent of *over training* the skills to the point of automatic and effortless execution of basic skills so that drivers' cognitive capacity would be freed for contextual problem solving in the field. The number and variability of practice trials would not seem to be sufficient to reach such a level of learning. Instead, HPLC is relying on both repetition and spacing of practice to come from the recognition component of the truck backing training program—which trainees will engage in before, during, and after the closed-course motor training sessions. In the recognition training component, trainees will be able to get far greater repetition of trials and variability of situations—although practicing without the motor skill production component.

Assessment of Performance. HPLC would have liked to arrange a post-training retention and transfer test that returned trainees to the closed course after they had completed both the *Steer Your Rig* and *Trust Your Mirrors* components of the *Back to the Future* training program. A final assessment of individual trainees' performance improvement as well as summative assessment of the training program could be accomplished using a set of representative backing maneuvers similar to those used in the closed-course training but with more contextual realism—for example, "dressing" the closed course with real or mocked-up cars, trees, power lines, and pedestrians. However, the client's reluctance to remove drivers from the road makes a closed-course assessment unlikely.

Instead, HPLC decides that trainees reaching criterion performance within both the closed-course production skills training and the online recognition skills training meet certification requirements, to the satisfaction of PJF Fleet and DAS customers, that drivers are ready to confidently and competently handle the variety of backing maneuvers that the customers' urban locations offer.

Mirror-Trusting Practice. The cognitive task analysis of truck-backing behavior that HPLC conducted had revealed that the two aspects of backing that drivers struggled with were the actual manipulations involved in properly orienting forty-eight-foot and fifty-three-foot trailers with a loading dock and with being able to use the mirrors on the tractor cab to avoid obstacles. So the *Steer Your Rig* closed-course training component is designed to improve the psychomotor production skills associated with manipulating the trailer in various types of backs. The *Trust Your Mirrors* component focuses entirely on the recognition aspect of backing.

Design Issues for *Back to the Future*

At this point, HPLC has to make decisions about a number of training issues based on instructional design theory and on their own research into training these advanced learners. These design issues include:

- "Off-book" behavior by experts;
- Recognition training: psychomotor (without the motor);
- Video-simulation on the Internet;
- Practice as implicit instruction;
- Simulation and fidelity;
- Producing video-simulation training; and
- Design of practice.

"Off-Book" Behavior of Experts. HPLC's analysis of the expert-novice study (representative backing tasks on the closed course) that they had conducted in the course of performing a cognitive task analysis (CTA) revealed two behavioral differences between the more experienced ("expert") drivers and the less experienced ("novice") drivers. One was that the expert drivers consistently took a longer time to start a backing maneuver, even in time-pressured trials. While both expert and novice drivers almost always conducted a walk-around before beginning a backing maneuver, the experts sometimes appeared to "take a moment" in the cab. Retrospective think-aloud protocols and follow-up interviews revealed that experts took the extra time to visualize the physical setting and to mentally rehearse the approach that they planned to take in order to get the trailer properly oriented to the dock.

This focus on *problem representation* is consistently found in expert performers in a range of domains, both psychomotor and cognitive. For example, in a classic expert-novice experiment, physics graduate students (experts) routinely took longer than undergraduate physics students (novices) to start solving physics problems—which the experts then completed more quickly than the novices (Chi, 2006). The mental rehearsal stage is also consistent with Gary Klein's model of *recognition-primed decision-making* (RPD). Klein and associates have studied fire marshals, neonatal emergency room nurses, and military field commanders and found that, when confronted with a performance situation, experts spontaneously generate a course of action and then mentally simulate the action being taken. If the outcome of the mental simulation is satisfactory, the course of action is undertaken. If not, then the expert engages a more effortful process to generate an alternative course of action (Klein, 1998).

The other observable behavior difference among the novice and expert backers was that, once they started a backing maneuver, the expert drivers got out of the cab (GOAL) many fewer times than the novice drivers did. "See, he doesn't trust his mirrors," said the SME while watching a video of a novice driver. The official PJF Fleet policy is that every backing maneuver should include at least one GOAL and that drivers should use a GOAL whenever they are uncertain of the proximity of their tractor or trailer to obstacles. The reality, however, is that drivers can lose control of a pressured situation with impatient "four wheelers" honking their horns or attempting to move around a tractor-trailer that is blocking traffic. Expert backing performance represented drivers using a GOAL when necessary, but also minimizing their use of this time-consuming and confidence-draining tactic.

As noted earlier, HPLC recognized a significant mismatch between the official policy and the observed behavior of experts—which is often revealed in a CTA. Another mismatch between policy and practice was that drivers were directed by policy to use a spotter to assist in executing backing maneuvers—or not make the delivery. However, drivers interviewed by HPLC consistently noted that spotters cannot always be recruited on site, and even when they are, spotters are not always consistent or reliable. The drivers' reality is that spotters are a luxury and that drivers need to be prepared to execute backing maneuvers without using spotters. HPLC checked with high-level PJF Fleet officials (primarily the V.P. of safety and operations) before committing to developing a training program based on expert behavior rather than official policy.

Recognition Training: Psychomotor (Without the Motor). HPLC had two goals for the *Trust Your Mirrors* recognition training component of *Back to the Future*. One was that the training would build the types of recognition skills demonstrated by experts. The second was that recognition training should be delivered, if possible, over the Internet so that drivers would need to leave the road and come to the close-course training facility only for the motor production aspect of training.

From the CTA it was clear that two types of recognition training were called for. The first would be oriented toward trainees learning and practicing *situation awareness*—that is, sizing up the delivery scenario in terms of deciding how to set up the backing maneuver in order to minimize the duration and extent of blocking traffic or otherwise being in an exposed position with the tractor-trailer. This type of strategic and deliberate "before the action" recognition skill is fully in the cognitive domain and was well within HPLC's experience to produce. HPLC would design two situation-recognition tasks. The first would require the learner to *identify* the type of setting that was depicted in graphical or photo-realistic views of a variety of docking situations. A second task would require learners to choose from alternative courses of action and *predict* the outcome of the chosen course of action.

This kind of training module was well within HPLC's experience and capability to produce and to delivery via the Internet. Situation-awareness training represents the type of cognitive problem-solving skill that is more fully considered in other chapters in this volume (see especially Chapter Ten, Instructional Strategies for Directive Learning Environments, and Chapter Twelve, High Engagement Strategies for Simulation and Gaming) and won't be described in detail here.

The second type of recognition skill, however, was outside of HPLC's previous instructional design experience. These are the type of recognition skills that have been studied and trained by sports expertise researchers, as described in an earlier section of this chapter. The appeal to HPLC of the recognition-only training approach was that it not only provided an approach to systematically training an essential aspect of expertise in the target skills of truck backing but that it could potentially be delivered over the Internet, thereby minimizing trainees' time at the close-course training center.

Video Simulation on the Internet. The traditional instructional design approach to training recognition skills is to combine recognition and production skills in realistic, whole-skill psychomotor practice activities. In domains such as aviation and surgery, whole-task training typically involves *simulation*, either "live" or using a simulator. It can be a very expensive approach, but one that is often justified by safety and cost issues with real-world training (Alessi & Trollip, 2001). For the *Back to the Future* project, however, HPLC decided to apply the theory and methods developed in sports expertise research to train recognition separate from rather than combined with psychomotor skill production.

The focus of the *Trust Your Mirrors* module was to have trainees practice making judgments about the "perimeters" of their tractor and trailer *during* backing maneuvers. The expert drivers participating in the CTA had repeatedly emphasized the importance of drivers being aware of not only the back end of the trailer but also the top of the trailer and the steps, fuel tank, and tires of the tractor. Drivers could get so focused on maneuvering the trailer into docking position and avoiding obstacles that it would be easy to overlook the other perimeters on the tractor as well as the trailer.

The instructional objective of the *Trust Your Mirrors* module, therefore, was

> "Given photo-realistic (video) images depicting the driver-side and passenger-side mirror views of an in-progress tractor-trailer backing maneuver, the learner will detect any violations of the safe proximity zone of seen and unseen obstacles in relation to all of the tractor-trailer's perimeters."

Practice as Implicit Instruction. Within the HPLC design, trainees could potentially engage in the online recognition training before, during, or after engaging in the *Steer Your Rig* closed-course motor production training. The videos produced for use in the closed-course training module would be posted on PJF Fleet's training webpage—along with a link to the *Trust Your Mirrors* module—so that the videos could be reviewed by trainees if and when they felt they needed to have backing maneuvers demonstrated. However, the instructional goal of the *Mirrors* module would be achieved almost entirely through practice rather than instruction. Consistent with principles summarized earlier in the chapter, the advanced learners involved in the truck-backing training program would benefit most from implicit instruction in the form of externally focused *knowledge of results* feedback during practice trials and *augmented feedback* in the form of scores displayed during and after the online drills.

Simulation and Fidelity. Note that the instructional objective, and therefore the training design, does **not** include the trainee manipulating the movements of a virtual truck. This is an essential difference between simulators and video-simulation. As described by simulation researchers at the University of Central Florida's Institute for Simulation and Training, truck simulators are categorized into four levels of fidelity (Allen & Tarr, 2005; Tarr, 2006). Level Four is represented by full-size in-cab simulators with three-dimensional, computer-generated visual display, functional controls, and realistic movements of the truck cab. Such high-fidelity simulators cost between $500,000 and $2,000,000 and are typically, and appropriately, used for research rather than routine training purposes.

Level Three in-cab simulators, such as that shown in Figure 14.3, feature some cab motion and computer-generated through-the-windshield visual displays that change in response to learners' manipulation of a realistic steering wheel, gear shifter, and brakes. Level Three truck simulators typically cost $100,000 to $250,000 and are used for training as well as research. Level Two is represented by non-motion, partial-cab simulators that typically cost between $45,000 and $80,000 and are commonly used for training purposes.

Level Two simulators typically have realistic steering wheels, gear shifters, brakes, and instrument panels. Most modern truck simulators of this fidelity level still feature computer-generated graphic displays (although much less immersive) that change in response to trainee input via steering, shifting, and braking devices. In older multi-seat simulators, the display was video or film, and therefore not responsive to individual learners' input. As many as eight or ten trainees viewed the same projected display and still manipulated steering wheel and brake—but without the visual display changing in response. Level One is represented by desktop truck simulators that display animated graphics on a computer screen and may include non-realistic steering wheel and brake

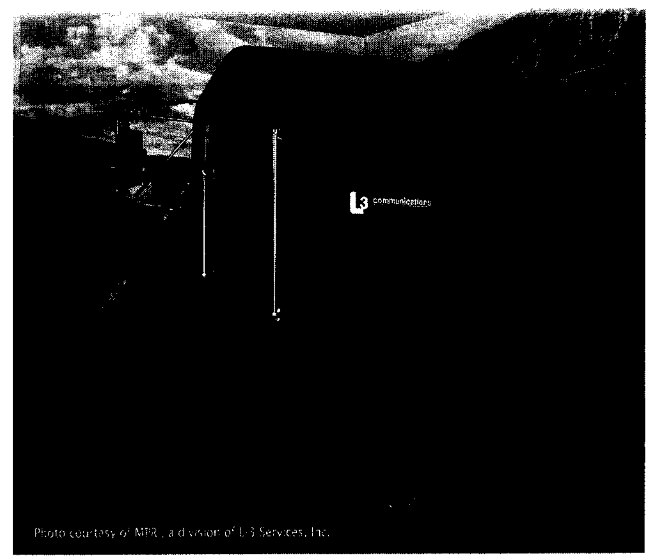

Figure 14.3 Level Three Truck Simulator.
Photo courtesy of MPRI, a division of L3 Services, Inc.

Figure 14.4 Level One Truck Simulator.
Photo courtesy of J. J. Keller and Associates, Inc., Neenah, WI

components—usually repurposed video game devices (see Figure 14.4). Level One simulators can be purchased for between $2,500 and $15,000 (Tarr, 2006).

The interesting and complex issue of fidelity in simulators is considered in detail in Chapter Twelve, *High Engagement Strategies in Simulation and Gaming* (in this volume). Here the key point is that the video-simulation approach is outside of the continuum of simulator fidelity (Tarr, 2006). In terms of responsiveness to learner input, video-simulation is very low fidelity. In fact, the internal training staff at HPLC was mystified as to why an apparently low-fidelity simulation was being used rather than the Level Two truck simulators that PJF Fleet owned and operated. HPLC explained that the volume of trainees could not be moved through the simulators in the target time frame. In addition, the *Back to the Future* training program already included very high-fidelity simulation in the form of the closed-course *Steer Your Rig* training. The online *Trust Your Mirrors* module would serve to both enhance and focus the live in-cab training.

Although the video-simulation approach might be cast as low-fidelity simulation, it should be noted that the video display is actually higher fidelity than the display in even Level Four truck simulators. If a visual display in a simulator changes based on user input, then the display needs to be computer generated. The realism of the computer graphic program's interpretation of visual objects and movement, then, becomes a limiting factor in the realism of the display.

Video display of a driver's view through the windshield or of side mirrors is actually more realistic, if not responsive.

Clearly, the learning objective in recognition training requires a realistic visual display, so this is a case where a low physical fidelity, high cognitive fidelity simulator is more appropriate than a high physical fidelity but low cognitive fidelity simulator (Foshay, 2006). Indeed, cognitive load theory would argue that high physical fidelity in this case is not only not unnecessary but may actually produce *extraneous cognitive load* that interferes with the target learning (van Gog, Ericsson, Rikers, & Paas, 2005).

Producing Video-Simulation Training. HPLC realized early in the project that the videos and the software programming for the video-simulation activity could have use across the trucking industry and the truck driver training industry. HPLC negotiated with PJF Fleet to have the client pay 25 percent of the cost of developing instructional materials and software with HPLC picking up the rest. In return, HPLC would own the video footage and software programming and PJF Fleet would have a standing license to use it.

HPLC's design for the video-simulation activities was to videotape actual trucks backing into actual locations and covering all four types of backing (sighted straight line, blind straight line, sighted jack knife, blind jack knife). A video production company was contracted to shoot and edit the videos for the video simulation. Four video cameras were used to shoot each truck-backing maneuver. One camera was fixed to view the driver's view of the driver-side mirror and another camera was fixed to view the driver's view of the passenger-side mirror. A third camera was placed behind the truck and simulated a GOAL (get out and look) by the driver. A fourth camera was positioned on a boom about twenty-five feet in the air and placed around fifty feet in front of the truck as the truck was in position to start a backing maneuver. This "bird's eye" camera is typically offered as a computer animation in truck simulators to help build drivers' association between what they can see in their mirrors or a GOAL and the actual position and spacing of objects.

At each videotaping location, each of the types of backing maneuvers was videotaped repeated times with slight variances between backing repetitions. Some backs were executed perfectly, while others depicted a variety of backing miscues. The SME assured that every type of miscue was videotaped and kept a log sheet coding each back. The set of backs was recorded with both a standard-length (forty-eight-foot) trailer and a long (fifty-three-foot) trailer. Each approach was then edited in an identical format with all four camera angles depicting the same action and coded for type of backing maneuver, type of trailer, and type of miscue (if any). Computer programmers at HPLC then licensed an interactive sports training software program and adapted it to fit the truck backing content.

HPLC designed a series of training drills that required learners to pause the video when they detected a backing miscue and then to check the GOAL camera view. A point scoring scheme, which represents augmented rather than intrinsic feedback, was devised that gave trainees a beginning score and then subtracted points for each GOAL taken, but subtracted more points for violating the designated proximity zone of objects on any of the trucks' perimeters. The scoring scheme rewarded learners for extending beyond their comfort zones in "trusting their mirrors" but without missing any miscues. As with any drill methodology, the goal was for learners to increase their speed while maintaining their accuracy. The drill characteristics of *repetition, feedback,* and *progressive difficulty* were enacted in the video-simulation program (Alessi & Trollip, 2001).

About two hundred video items were produced (ten instances of four types of backing maneuvers at five locations). The item pool for each drill could be designated by type of backing maneuver or by location. Because the items were formatted in the same way, the items could be randomized for presentation, meaning that learners could engage the video-simulation program repeated times. While some items would be repeated, the order of presentation would be different each time. Progressive difficulty could be set by the learner through selecting more difficult backing maneuvers and/or locations. More difficult maneuvers and more difficult locations provided more scoring points.

The key instructional design element of the video simulation was that learners did not manipulate the truck or the mirrors in any way. The learner interacted with the program by *detecting* miscues based on mirror views. In usability testing of the video-simulation program with non-PJF Fleet drivers, participants rated it as challenging but not stressful, and participants consistently underestimated the time that they spent on the *Trust Your Mirrors* drills, suggesting a high level of engagement. A number of usability participants expressed a desire to try the program again in order to beat their own scores or to beat the best score of another participant.

Design of Practice. Consistent with long-established guidelines that suggest providing mature and motivated learners with a high degree of learner control (Alessi & Trollip, 2001), *Trust Your Mirrors* drills were designed so that learners could select and create drills themselves and to decide for themselves when to advance to different or more difficult drills. HPLC produced an introduction video in which the SME explained the benefits of *blocked, spaced, variable,* and *random* practice. He also advised trainees to turn the obstacle warning system on during initial learning and early practice but turn it off for later practice and self-testing. The trainee would make the choice, although the *best scores* display on the PJF Fleet training web page would only record scores achieved with the warning system off.

Video-Simulation Test. HPLC's design for assessment in the *Back to the Future* training program required PJF Fleet trainees to register and log in on PJF Fleet's training website to engage in video-simulation drills. Trainees could engage pre-selected drills or could mix and match to make new drills. When the trainee felt ready, he or she selected *test* mode in which the system did not provide feedback and the final score was saved in a database. PJF Fleet offered drivers reward gifts from the company's gift catalog (used to motivate a range of desired driver behaviors) based on the number of *Back to the Future* drills completed and for the high score on selected drills. When a driver met criteria for performance on the *test* drills and had previously met criterion performance on the closed-course backing drills, then the driver was certified as qualified for DAS assignment.

Consideration was given to devising a *performance-based test* of the complex psychomotor skills of backing a tractor-trailer, perhaps by "dressing" the closed course to simulate prototypical urban loading dock scenarios. Without a whole-task, high-fidelity simulation test, it was impossible to be certain that the motor *production* component and the *recognition* component that had been de-coupled for training purposes would be successfully re-coupled with a measurable improvement in performance. However, while truck backing performance is important and mistakes are costly, it isn't in the same category as surgery or aviation, and the cost/benefit consideration didn't justify the cost of creating and implementing a high-fidelity *transfer* test.

As in most training evaluations, satisfaction of learners and client would be measured as well as learners' achievement of the defined objectives of the training program. Measures of performance, and therefore measures of transfer of learning to performance, remain elusive (except in sports) and are usually beyond the interest and ability of corporations or institutions to pursue. While transfer from training to performance might not be measured as often or as thoroughly as we would like, some value can come in the form of *pseudo-transfer* from one simulated environment to another (Lee, Chamberlain, & Hodges, 2001). If and when PJF Fleet's internal training department programs backing scenarios into their in-house simulators (which would be appropriate for training current and future drivers who are not able to attend the *Steer Your Rig* closed-course training sessions), then correlating scores on the simulator with scores on the closed-course tasks and the video-simulation drills could become very interesting. It would be expected (but would be worth investigating) that recognition skill training alone or production skill training alone would not lead to as much improvement in whole-skill performance (in the truck simulator) as would the separate but complementary training of the production *and* recognition skills that make up this complex psychomotor performance.

CONCLUSION

After summarizing current theory and practice of psychomotor training by providing lists of principles and guidelines, I have used the hypothetical *Back to the Future* scenario to illustrate the benefits and demonstrate the process of designing part-task training that addresses motor production skills and recognition skills separately but equally. This paradigm-shifting approach is based on sports expertise studies that date back at least to Haskins' (1965) film-based training of tennis serve recognition, and researchers in sports science continue to conduct video-simulation studies in a widening array of sports (Ward, Williams, & Hancock, 2006).

The sports scientists and cognitive psychologists who are conducting recognition training programs are beginning to investigate instructional design questions that are of interest to teachers, trainers, and instructional designers—and serve as a model for instructional design research and practice. For example, studies have investigated the use of explicit versus implicit instruction (Smeeton, Hodges, & Williams, 2005) and internal versus external focus of attention (Castaneda & Gray, 2007). Beyond sports, a group of researchers is adopting recognition research and training methods developed in sports science to domains such as use-of-force decision making by military and law enforcement personnel (Tashman, Harris, Ramrattan, Ward, Eccles, Ericsson, Williams, Roderick, & Lang, 2006) and critical care nursing (Ward, 2008). The leading researchers in the area have also published in a special issue of *Military Psychology* dedicated to connecting sports science findings and methods to military training (Eccles, 2008; Ward, Farrow, Harris, Williams, Eccles, & Ericsson, 2008; Williams, Ericsson, Ward, & Eccles, 2008).

Sports provide a natural context to draw from in designing training of psychomotor skills. It also provides a rich test bed for research and training in psychomotor learning and performance, in part because athletes and coaches have a "culture of practice" (MacMahon, Helsen, Starkes, & Weston, 2007) that other professions don't have and partly because performance is so much more clearly observable and measurable in sports. However, the implications of this recognition-training line of research make it worth investigating as a training approach in a wide range of domains (Fadde, 2007). With the continued improvement of video transmission over the Internet and the growth of web-based training in general, the potential for systematically training essential recognition aspects of expert psychomotor performance using video-simulation delivered online is enticing.

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