Look 'Ma, No Hands: Part-Task Training of Perceptual-Cognitive Skills to Accelerate Psychomotor Expertise

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ABSTRACT

Emerging sports science research reveals that expert performance in rapid and reactive skills such as baseball batting, return-of-serve in tennis, and goalie play in hockey and soccer is based on superior perceptual-cognitive skills that allow a competitor to perceive predictive cues in an opponent's actions. Situational decision-making, such as the pass/dribble/shoot decision of soccer or basketball players and the run/pass recognition of football linebackers, also relies on perceptual-cognitive skills. Sports science researchers have developed video-occlusion as a method for isolating and measuring perceptual-cognitive skills separate from psychomotor execution of the skills. Using an expert-novice research paradigm, athletes of varying skill levels are shown point-of-view video clips of an opponent executing an action. Clips are occluded, or masked, to reveal expert advantage in identifying and predicting the actions of the video opponent. In spatial occlusion portions of the video display are masked to study *where* experts look to pick up predictive information. In temporal occlusion the video display is cut off at various points during playback to study *when* experts pick up predictive information. Some researchers, including the author, have repurposed the video-occlusion method in order to systematically train sport-specific perceptual-cognitive skills. Training-based studies show that perceptual-cognitive skills can be improved through video-occlusion training and, further, that performance of the full sport skill can be improved. The implication for training of complex psychomotor skills in military contexts (e.g., vehicle operation, use-of-force, emergency response) is that perceptual-cognitive component skills associated with expert performance can be identified, isolated, and trained using video-occlusion methods that are less expensive and more portable than high-fidelity simulator-based training.

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INTRODUCTION

This paper describes sports science research on perceptual-cognitive skills that underlie expert performance in many reactive, fast-action sports skills. This sports expertise approach has far-reaching implications for the training of expert psychomotor performance in domains such as vehicle operation, use-of-force, and emergency response; skills which are often trained using simulators that involve trainees performing the whole skill in a realistic environment. In training advanced levels of certain performance skills, however, it may not be necessary or even optimal to practice the whole skill in a highly realistic environment.

Sports expertise research suggests that *recognition* and *production* components of psychomotor performance skills can be de-coupled for targeted, part-task training and then re-coupled for transfer to whole-skill performance (Fadde, 2009a). While production components of psychomotor skills are routinely isolated for training, recognition (i.e., perceptual-cognitive) components are typically developed through whole-task activities such as simulation. Indeed, the thrust of modern instructional design theory is to incorporate whole-task learning activities earlier and more often (Lim, Reiser, & Olina, 2008).

In contrast, an instructional design approach that extends part-task training to include not only production components but also recognition components offers two distinct advantages in the training of psychomotor performance skills. One is an *impact* advantage as the approach targets elusive skills that underlie the superior anticipation and rapid response of expert performers. The other is an *opportunity* advantage as part-task training of recognition skills can be accomplished using laptop computers and mobile devices. Separate part-task training of recognition and production skills doesn't replace whole-task simulator-based training but rather reserves it for final testing and improving transfer of training to performance.

Sports expertise research not only supplies a theoretical foundation and research findings that support a recognition training approach but it also supplies methods for training expert recognition skills. These methods, which were developed by sports science researchers in order to test the recognition skills of expert and less expert athletes, have been re-purposed in order to train the same sports skills (Ward, Willams, & Hancock, 2006).

Researchers have also begun to investigate the extent to which sports expertise research findings and training methods apply to wider domains of performance (Ward, Suss, & Basevitch, 2009), including military performance skills (Ward, Farrow, Harris, Williams, Eccles, & Ericsson, 2008). At this point, the research base not only supports training applications but also requires application to advance theory. In this paper I describe the sports expertise research and then describe in detail my research-based program to train *pitch recognition*, the perceptual-cognitive component of baseball batting. I then apply what I call the expertise-based training approach (Fadde, 2009b) to designing a hypothetical program to train recognition components of psychomotor performance skills in the non-sports domain of truck driving.

SPORTS EXPERTISE RESEARCH AND TRAINING

Athletes, coaches, and sports fans recognize and prize expert performers who seem able to "read" match situations, anticipate opponents' actions, and execute extremely rapid performances -- while seeming to have "all the time in the world." Since the early 1980s, sports scientists have studied what they term *sports expertise* in a variety of fast-action sports including tennis, baseball, cricket, hockey, soccer, volleyball, and basketball. Research across these sports consistently reveals that expert performers have superior recognition skills, which can be further broken down into *perceptual-cognitive* and *decision* skills (Williams & Ward, 2003).

Perceptual-cognitive skills are ballistically reactive skills such as batting in baseball, returning serve in tennis, and blocking shots-on-goal in hockey and soccer -- skills in which athletes select and execute a response in time frames that challenge simple human reaction time. Decision skills also involve rapid recognition and response, but in more generous time frames of a couple of seconds. Examples include the dribble/pass/shoot decision of soccer, hockey, and basketball players as well as defensive play in team invasion sports such as American football.

Expert-Novice Research Paradigm

Sports expertise research is closely aligned with the expert performance approach that is associated with K. Anders Ericsson and colleagues. The approach adopts the expert-novice research paradigm that was introduced in classic chess studies (e.g., Chase & Simon, 1973) and that has been also been applied in studying expert performance in domains ranging from physics problem-solving to music to dance (Ericsson, Charness, Feltovich, & Hoffman, 2006).

Typically, expert-novice studies involve devising a representative task and then comparing the performance of more skilled (expert) and less skilled (novice) performers on the task. Constraints are often imposed in order to reveal particular aspects of the task performance that most clearly differentiate expert performers from less skilled performers. In sports expertise research, the representative tasks usually involve participants recognizing the actions of an opponent, such as a baseball pitcher or a tennis server, and anticipating the outcome of the opponent's action.

Video-Simulation / Occlusion Method

Sports science researchers have developed the video-simulation method to compare the sport-specific recognition skills of expert and novice athletes. In the video-simulation research method participants view a video showing an opponent in action. In studies of perceptual-cognitive skills such as baseball batting and return of serve, the video shows an opponent making a pitch or striking a serve. Participants are directed to identify the type of pitch or serve and to predict the ultimate location of the ball in the strike zone. Basketball, hockey, and soccer players are shown video clips and decide whether to pass, dribble, or shoot.

The video, which is recorded from the internal point-of-view of a competing player, is *occluded* so that participants are forced to identify or predict based on limited visual information. Spatial occlusion involves masking portions of the visual display. For instance, video of a tennis server is occluded so that the racquet or the server's proximal arm or the server's head or the ball is masked. When the experts' predictive advantage disappears in a particular occlusion condition, then researchers surmise that the occluded portion of the visual display was a source of predictive information for experts.

Temporal occlusion involves cutting off the video playback at various points in the movement of the video opponent or the resulting ball flight. Again, when the experts' advantage disappears then the visual information that was cut off is surmised to have contained important predictive information. Figure 1 depicts a video-simulation, temporal occlusion task used to measure the pitch recognition skills of more and less skilled baseball players.

Figure 1. Video-Simulation of Pitch Recognition

Baseball Pitch Recognition Research

A typical professional baseball pitcher's fastball thrown at 86 miles-per-hour takes approximately 450 milliseconds to travel from the pitcher's hand to home plate, 60 feet and 6 inches away. Batters typically take around 200 milliseconds to swing their bat, leaving batters about 250 milliseconds (literally the blink of the eye) to decide if and where to swing the bat.

Using the video-simulation, temporal occlusion method, Paull and Glencross (1997) studied baseball batters from the Australian professional leagues. Expert batters ("A" league) were significantly superior to novice batters ("B" league) at the component skills of recognizing the type of pitch (fastball or curveball) and predicting the location of pitches in the hitting zone.

Paull and Glencross tested expert and novice batters' pitch recognition skills in a variety of temporal occlusion conditions. Occlusion points ranged from video edited to black after showing about half of the pitch's ball flight to video edited to black before the pitcher released the pitch. The researchers found that expert batters were significantly better at identifying pitch type at occlusion points between Moment of Release (MOR) of the pitch and MOR plus about one-third of ball flight. At occlusion points beyond one-third of ball flight the expert and "novice" (less expert) batters were equally proficient and at occlusion points before MOR both groups were reduced to chance guessing.

Baseball Pitch Recognition Training

I repurposed the pitch recognition tasks that Paull and Glencross used for measuring pitch recognition skills in order to *train* pitch recognition skills (Fadde, 2006). Based on the expert-novice research, I used occlusion points of MOR + 5 frames of video (167 milliseconds or about one-third of ball flight), MOR + 2 frames of video (67 milliseconds of ball flight), and MOR. While the research design mixed occlusion conditions to avoid learning effect, the training design used different occlusion conditions to create progressive difficulty (MOR+5 to MOR+2 to MOR), a component of the drill-and-practice instructional method. The training design also included other components of drill-and-practice method, such as immediate feedback and individual pacing (Alessi & Trollip, 2001).

The pitch recognition training program was implemented with a National Collegiate Athletic Association Division I baseball team. During the team's normal pre-season winter practice sessions half of the batters on the team were provided with pitch recognition training. The other batters on the team acted as a control group and received extra batting practice for the same amount of time as participants received pitch recognition training. To create equivalent treatment and control groups the team's coaches first ranked the batters in terms of overall batting ability. I then paired adjacent batters in the coaches' ranking and randomly assigned one to the treatment condition and the other to the control group using a matched-pair, random assignment design.

Training Program Design

The stimulus video depicted four pitchers on the cooperating team, two left-handed pitchers and two right-handed pitchers. Video was shot using Betacam format video camcorders placed on head-high tripods in both the right-handed and left-handed batters' boxes. 20 pitches were selected for each of the four pitchers and three occlusion versions of each pitch were edited (MOR, MOR+2, MOR+5).

Video clips of each pitch and occlusion condition were associated with data representing the pitcher, the occlusion condition, the type of pitch, and the location of the pitch in the strike zone. Ten 15-minute individual training sessions were conducted with nine players in the treatment condition. As in the research method, the training method focused on two pitch recognition sub-skills: *identifying* the type of pitch being delivered and *predicting* the ultimate location of the pitch in the strike zone. The training was divided into four drills. In each drill the researcher/trainer played selected video clips on a projection television. Participants sat twelve feet from the display to represent a realistic viewing angle. In all drills, participants viewed 20 pitches from each pitcher at a designated occlusion point. If a participant's score reached criterion then the researcher/trainer advanced the participant to the next difficulty level of the same drill. If the participant's score did not reach criterion then the drill was repeated at the same occlusion level. The four pitch recognition drills were:

Pitch Type. Participants called out loud the type of pitch being delivered by the video pitcher. The researcher/trainer recorded participants' input and provided verbal feedback. Participants started at MOR+5 and advanced to MOR+2 and ultimately to MOR (pitches cut off at the moment of release).

Pitch Location - Known Type. Participants viewed blocks of pitch types (all fastballs, all curveballs) and predicted the location of the pitch in the strike zone. The participant called aloud a location number as determined by a nine-cell strike zone grid (see Figure 2). The researcher/trainer provided verbal feedback. Participants progressed from MOR+5 pitches to MOR+2 versions of the same pitches. Participants were not shown MOR clips, as some ball flight is necessary to predict location.

1	2	3
4	5	6
7	8	9

Figure 2. Strike zone grid.

Pitch Location - Unknown Type. Participants were shown pitches of mixed type and predicted the location. To reach criterion on the Location-Unknown Type drill it was assumed that participants needed to recognize pitch types and use the information, along with whatever amount of ball flight was shown, to predict the location of pitches in the strike zone.

Zone Hitting. Participants pre-selected up to four connected cells of the nine-cell strike zone grid to represent their preferred hitting zone. With each pitch participants then verbalized "Hit" or "No" to input their prediction of whether the pitch would be in the selected hitting zone or not. The drill put the raw pitch recognition skill into a realistic batting context.

Pitch Recognition Training - Results

The dependent variables were game batting statistics from the team's 18-game pre-conference schedule of games. Figure 3 shows official NCAA batting statistics of Batting Average, On-Base Percentage, and Slugging Percentage. These three statistics are thought to represent different aspects of batting ability.

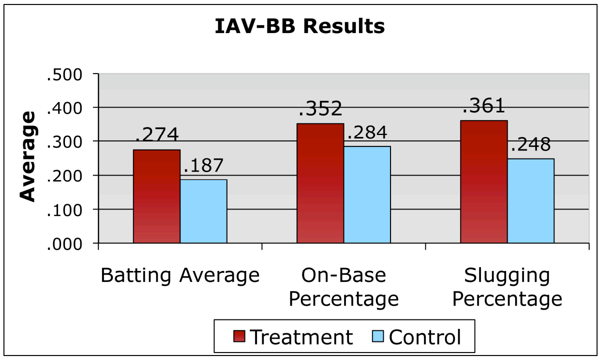

Figure 3. Batting Statistics.

Statistical significance of differences between the pitch recognition training group (treatment) and the control group were established using the Mann-Whitney Rank Correlation *u*-test, calibrated for small *n* (see Figure 4). The difference between groups was statistically significant ($p<.05$) for batting average ($p=.047$)) and was not statistically significant for on-base percentage ($p=.120$) and slugging percentage ($p=.155$).

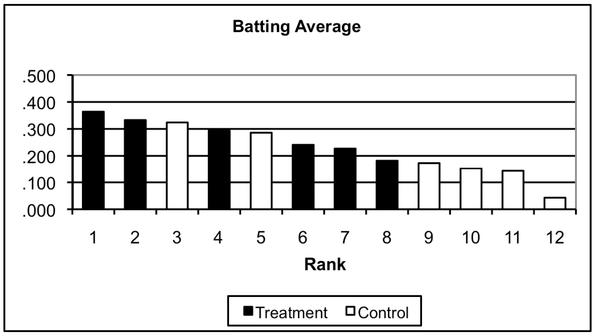

Figure 4. Rank Correlation.

These findings suggest that a limited but focused part-task recognition training program (ten 15-minute sessions) led to improvement in the game batting performance of already advanced baseball players.

Video-Simulation versus Simulator

I have reduced video-simulation pitch recognition training to a laptop computer (see Figure 5) and have undertaken a series of studies that are intended to improve the training product rather than to produce generalizable research results. These studies with authentic, competing baseball and softball players show that players accept the laptop format; vastly increasing the mobility of the training program. Players are now able to practice the pitch recognition component of batting on a laptop computer during team road trips.

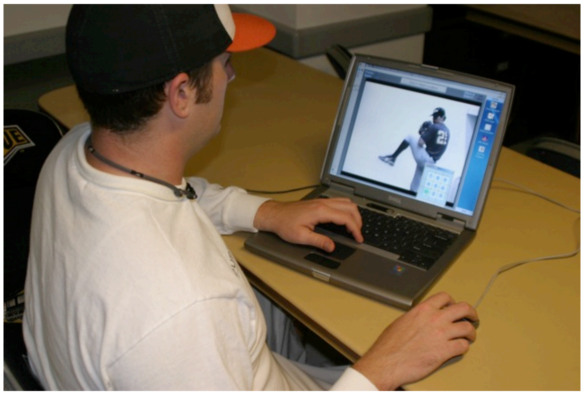

Figure 5. Pitch Recognition on laptop.

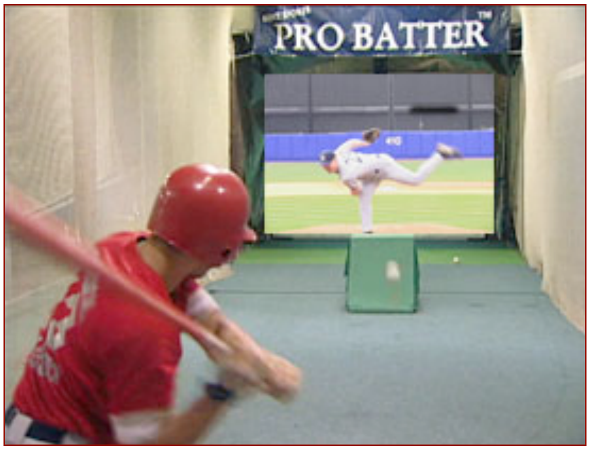

Figure 6. *ProBatter* video pitching machine.

The part-task video-simulation approach can be compared to a whole-task simulator in the form of *ProBatter* (see Figure 6), a video pitching machine that is used by several major league baseball teams.

ProBatter incorporates a pitching machine hidden behind a video projection screen. The pitching machine can be set to "throw" a variety of pitches (fastball, curveball, slider). A video image of a pitcher is projected onto the screen and the machine propels a ball through a small hole in the screen, synchronized with the pitcher's release point. The batter hits the "pitch," thereby practicing the whole batting skill.

As realistic as *ProBatter* is, the image of the pitcher does not change with the different types of pitches delivered by the hidden pitching machine. The system, therefore, does not offer batters the key predictive cues available from the pitcher's release of the pitch. In the two-second window for recognizing pitches video-simulation on a laptop computer is higher fidelity.

Whether the *ProBatter* simulator or the pitch recognition video-simulation program is more effective would be an interesting research question. In essence, though, they are training different aspects of the extremely complex psychomotor skill of baseball batting. An optimal training program might well include both methods, depending on the skill level of the trainee and the training opportunity. For instance, professional baseball players spend considerable time on airplanes; time that could be used for laptop-based pitch recognition training.

Video-Simulation Training of Decision Skills

While sports expertise research has focused largely on perceptual-cognitive skills such as baseball batting and return-of-serve in tennis, there has also been research on *decision skills* in open-play sports contexts. Decision skills in the context of psychomotor performance differ from decision-making skills associated with a command-and-control level. These decision skills are involved in on-the-ground decisions that are based on rapid recognition of changes in the environment that are linked with the execution of motor skills. Instead of the half-second of perceptual-cognitive processing to choose and execute a response, open play decision skills such as pass/dribble/shoot in hockey, soccer, and basketball afford the athlete a couple of seconds to choose and execute a response.

Although they have been studied less than perceptual-cognitive skills, sports decision skills would seem to be more similar to non-sports psychomotor performance skills. For example, the decision skills of an American football linebacker share some characteristics with use-of-force decision-making by military or law enforcement personnel. Figure 7 shows a football player engaged in self-directed video-simulation training. Figure 8 shows a video-based use-of-force simulation (Advanced Interactive Systems, 2010).

Football video-simulation uses existing opponent scouting video. Different than television coverage, each play on scouting video consists of a high sideline angle that keeps all 22 players in the picture followed by an end-zone angle that focuses on the middle of the action. Video-simulation training uses a *decision edit* that does not show the full football play but rather shows the sideline angle for a few seconds up to the "snap" of the ball and then switches to the end-zone angle, showing the first second after the snap before being edited to black. Within the three-second recognition window (two seconds pre-snap, one second post-snap) the trainee calls out the opponent team's offensive formation, personnel group (the number of running backs and tight ends) and backfield set. These *reads* indicate whether the opponent team is executing a run play or a pass play. Anticipating run/pass is a key aspect of expert football performance.

Figure 7. Video-Simulation Training in Football

Figure 8. PRISim Judgment Training Simulator.

Like pitch recognition training in baseball, decision training for football players is part-task and targets a precise decision window for drill-and-practice. That contrasts with video-based use-of-force simulators (see Figure 8) in which realistic scenarios are depicted and change in response to actions of the trainee, including firing a weapon.

Implications for Simulator-based Training

Whole-task simulators like *ProBatter* and *Prism Judgment Trainer* have obvious value. However, whole-task simulators are expensive to develop and also expensive to use as trainees must be removed from the field to a central training location. In addition, the complexity of producing interactive scenarios means that relatively few interactive scenarios can be created. Whole-task simulators are most appropriate for late-stage transfer training and certification level testing but may not be necessary, or even appropriate, for the drill-and-practice type of training that builds perceptual-cognitive skills.

The cost of developing and delivering high-fidelity, whole-task simulator-based training in domains such as aviation and surgery is often justified by comparing it to even higher fidelity training using, for example, real aircraft or cadavers (Fletcher, 2009). However, many psychomotor performance skills that involve rapid recognition and response selection can potentially be trained more efficiently and more effectively by including video-simulation training of recognition skills in a simulator-based training program.

DEVELOPING RECOGNITION TRAINING

This section outlines a hypothetical video-simulation approach to train recognition skills in the domain of truck driving. While it is not yet an industry standard, more and more commercial truck drivers encounter simulator-based training at some point in their careers. Some use simulators in initial training; others receive refresher safety training using simulators. Recognition-based training is appropriate for drivers who have largely mastered the substantial skill set of manipulating a 48-foot or 53-foot tractor-trailer. Recognition training is intended to hasten drivers' progression from competency to expert level.

Truck Simulator Fidelity

Truck simulators can be divided into four levels of fidelity (Allen & Tarr, 2005), ranging from PC-based Level I simulators (see Figure 10) to Level IV truck simulators (see Figure 9) that offer very high fidelity including haptic feedback. Essentially, the levels represent overall fidelity, with a lower-level simulator representing a scaled-down version of a higher-level simulator. What is missing is *targeted* fidelity that is possible with part-task approaches to training either the recognition or production components rather than the whole skill. For example, the Level IV simulator in Figure 9 has very high fidelity input including steering, braking, and gear shifting. The display, however, is fairly low fidelity. Because the display needs to change in response to trainee input it must be computer-generated. Figure 10 shows a Level I truck simulator that is scaled down in order to be more portable and more economical. The simulator still takes and responds to trainee input of steering, braking, and shifting functions and still responds to learner input with changes in the computer-generated display.

In contrast, a video-simulation approach to training truck driver recognition skills could forego trainee input altogether and instead focus on high-fidelity visual display depicting authentic driving conditions as perceived through a truck's windshield and side mirrors. If we model expertise in truck driving as similar to sports expertise, then we would expect expert-novice research to reveal that expert drivers enjoy an advantage that is based on situation awareness and anticipation more than on superior execution of production skills.

Figure 9. Level IV truck simulator (L-3, MPRI)

Figure 10. Level I truck simulator (J. J. Keller)

As with baseball pitch recognition and football pre-snap reads, video-simulation training of truck driver recognition skills can use photo-realistic rather than computer-generated display that can potentially be both less expensive to produce and offer higher targeted fidelity (see Figure 11).

Figure 11. Video display for recognition training.

Designing Truck Driver Recognition Drills

Key instructional design issues involved in developing recognition training drills include:

1) What recognition skills to target,
2) What stimulus visuals to use, and
3) What representative tasks to devise.

In designing truck driver recognition training, the S.I.P.D.E. model (Scan, Identify, Predict, Decide, Execute) used in driver training suggests several training tasks. All but the Execute step can be trained using video-simulation. A drill might require trainees to *scan* short video clips of road driving situations and decide whether the situation requires heightened attention. If a video clip is correctly selected for further attention then the trainee can be cued to *identify* the particular threat in the video clip, and then to *predict* outcomes of various actions that might be taken.

With video-simulation training targeting drivers' *situation awareness* (Endsley, 2006), then the Execute stage can be adequately practiced in a lower fidelity truck simulator (Level I or II) if it accurately matches the reactions of various tractor/trailer configurations to combined steering, braking, and shifting actions made by the trainee. It isn't necessary to provide the elaborate scenarios, detailed visual display, and haptic feedback associated with high-fidelity truck simulators. Sessions in a high-fidelity simulator can be reserved for transfer-specific training and certification-level testing (Fadde, 2009c).

Video and Expert-Model Feedback

In many situations, video-simulation training can make use of existing video or video that can be recorded in the field. Stimulus truck driver video, for example, can be recorded in-cab to show a driver's view through the windshield and view of the side mirrors. Obviously, field recorded video would not be likely to capture a full range of road driving scenarios, especially scenarios with crash or near-crash outcomes. On the other hand, producing staged driving scenarios can be expensive. However, if the training is focused on situation awareness and not on driving responses then it isn't necessary to depict actual consequences but rather situations that have *potential* consequences.

In a repurposing of the expert-novice research method, video-simulation items can be created by having expert truck drivers view stimulus video clips and indicate if the situation calls for heightened attention (Scan) and, if so, where and what constitutes a threat (Identify), and what the potential outcome is (Predict). Judgments of experts who complete the recognition training tasks provide *expert model feedback* that can lead trainees to developing situation awareness that is more like that of experts; to "see" situations as experts do.

DISCUSSION

Sports expertise training of pitch recognition and football reads as well as the hypothetical truck driver recognition training apply an instructional design theory called *expertise-based training* that involves repurposing the methods of expertise research in order to systematically train aspects of expertise identified through research (Fadde, 2009b). In this paper my goal was to describe how this approach developed in the realm of sports expertise research and how it might be applied to accelerating the training of expert performance in a wide range of reactive psychomotor performance skills including those found in military contexts.

The operational principle of the recognition training approach is that recognition component skills can be trained separate from production component skills, thereby amplifying the instructional efficiencies that have long been associated with part-task training of production skills. The approach is by no means uncontroversial. Researchers within the sports expertise area who take an *ecological psychology* view maintain that the perception-action link in reactive sports skills cannot be de-coupled, for research or training purposes, without changing the essential quality of the skill (Abernethy, 2009). The implication of pitch recognition training, though, is that even this ballistic psychomotor skill -- with the entire perception-action sequence taking less than one-half second -- is amenable to part-task training that involves de-coupling the perception-action link for targeted training and then re-coupling the link for transfer to performance.

We need more research to determine what kinds of performance skills are amenable to recognition training. We need more research on decision-making in open-play sports, which would seem to have more direct applicability to training warfighters. Still, the potential for accelerating the development of expertise in reactive psychomotor skills, and at modest cost, should encourage trainers to explore video-simulation training in a wide range of performance domains.

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