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Interactive Video Training of Perceptual Decision-Making in the Sport of Baseball

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This study builds on a body of research in sports science that has used video as a means of measuring and training perceptual and decision-making skills in a variety of sports. Expert-novice studies using a video occlusion method have shown that expert athletes are able to make better and earlier recognition of an opponent's action, such as a baseball pitch, priming a rapid response. Training using video occlusion targets the time frame, measured in less than one-half second, which is associated with expert perception and decision-making. This is the first such study to measure transfer of video training to game performance. Video training in pitch recognition was associated with significantly better batting averages for college baseball players, as measured by rank correlation. The part-task approach has implications for training expert perceptual decision-making in other sports and in areas beyond sports, such as emergency response, vehicle operation, and use-of-force training.

Keywords: Perception, Decision-Making, Expertise, Expert-Novice, Part-Task Instruction, Simulation, Sports, Baseball, Pitch Recognition.

INTRODUCTION

Experts in many skill areas are able to recognize situations, select an appropriate response, and execute the response in time frames of less than

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one second. The cognitive component of such reactive skills is sometimes called perceptual decision-making (PDM), meaning extremely rapid decision-making based primarily on visual perception. An example is the use-of-force decisions made by police and military personnel. Emergency response situations and all kinds of vehicle operation, from personal car to fighter jet, involve PDM. PDM is also an essential aspect of reactive sports skills, like return of serve in tennis, blocking shots-on-goal in hockey or soccer, and hitting a pitched baseball. However, although PDM is recognized as an essential element of expert performance in such skills, it is generally conceded to come from instinct or massed experience and is not systematically taught. Training that targets PDM has the potential of getting more learners to expert levels of performance faster.

This training-based research project investigated the use of interactive video to improve the pitch recognition ability of baseball batters; pitch recognition being the PDM component of the complex psychomotor skill of batting. A major league average 86 mile-per-hour fastball takes 450 milliseconds to reach the batter. Most batters take about 200 milliseconds to swing the bat. Therefore, a batter has around 250 milliseconds to decide if and where to swing his bat. Ted Williams called it the most difficulty thing to do in sports (Williams & Underwood, 1970). The training approach used was based on sports science research grounded in cognitive information processing theory that supports separate training of the cognitive and physical components of a complex psychomotor skill. The key questions were whether advanced learners (Division I college baseball players) would accept mediated training of a "mental" skill and whether training the cognitive sub-skill of pitch recognition would lead to improvement in the overall skill of batting.

This research focuses on the area of sports for two reasons. One reason is that performance in sports is more contained, definable, and measurable than in areas like emergency response. Sports provide a laboratory in which to develop training techniques that may be applied to other areas. Another reason for focusing on sports skills is that there is a body of sports science theory and research that has focused on perceptual decision-making as an essential aspect of expert performance.

In this paper I will: 1) delineate PDM as a distinct domain of cognitive processing, 2) describe an interactive video training implementation that targeted the PDM skill of pitch recognition in baseball, and 3) consider how mediated PDM training can apply to "trained reaction" skills well beyond the realm of sports. These include use-of-force, emergency response, security, and vehicle operation.

LITERATURE REVIEW

Perceptual Decision-Making in Sports

Many sports skills require competitors to recognize visual cues, select a response, and execute the response in time frames that challenge simple human reaction time. Using an expert-novice paradigm, sports science research has shown that experts are able to make faster as well as more accurate decisions in situations that involve limited decision time and perceptual information (Chamberlain & Coehlho, 1993).

In these studies "expert" and "novice" participants were shown video or film clips depicting the point of view of a participant in a reactive sports situation such as defending shots-on-goal in hockey and soccer (McMorris & Colenso, 1996), blocking attacking shots in volleyball (Wright, Pleasants, & Gomez-Meza, 1990), batting a bowled ball in cricket (McLeod & Jenkins, 1991) or a pitched baseball (Paul & Glencross, 1997), and returning service in a variety of racquet sports (e.g., Abernethy, 1991). Participants were asked to make predictions about the outcome of the opponent's action. The visual display was either cut off at various points in time during the opponent's action (temporal occlusion) or portions of the display were masked (spatial occlusion) in order to test participants' ability to predict based on limited visual information.

While a substantial body of research has investigated differences between experts and novices in PDM skills, a small number of training-based studies have applied the findings and occlusion techniques of expert-novice research to improving PDM. In these studies participants viewed film/video clips of an opponent's action, such as a baseball pitch (Burroughs, 1984) or a tennis serve (Day, 1980; Haskins, 1965; Farrow et al., 1998; Scott, Scott, & Howe, 1998; Singer et al., 1994). Most of these studies have shown a positive effect of film/video-based occlusion training on improving PDM (Farrow, 1998) in the mediated training environment.

Definition of Pitch Recognition

At high levels of competition the baseball batter has less then 250 milliseconds to decide whether to swing the bat and where and when to direct the swing in order to coincide it with the arrival of the ball. That requires recognizing the type of pitch thrown in order to predict location of the pitch. Pitch recognition has long been recognized as an essential aspect of baseball hitting (see Fadde, 2002 for a review of instructional batting books). However, there is little agreement on what the skill of pitch recognition consists of and little advice on how to improve it. This is in great part because pitch recognition happens too quickly and subconsciously to be verbally explained by expert batters (Abernethy, Thomas, & Thomas, 1993).

While sports scientists have identified pitch recognition as an essential element of the complex skill of baseball hitting, they have not attempted to describe the cognitive processes involved. What the sports science research does do is to isolate where and when in the opponent pitcher's movements that expert batters are able glean useful information (Paull & Glencross, 1997). Sports science researchers focus on two components of pitch recognition: *identifying* the *type* of pitch being thrown (curveball, fastball, slider, changeup, etc) and *predicting* the eventual *location* of the pitch in the strike zone. These two components of pitch recognition are used as the operational definition of the skill for training as well as research purposes.

It is important to differentiate pitch recognition, as a form of perceptual decision-making, from the strategic decision-making that has long been a part of baseball lore and coaching. Ted Williams gives the definitive explanation of strategic decision-making in his seminal book *The Science of Hitting* (Williams & Underwood, 1970). Strategic decision-making happens before a pitch is delivered and is focused on anticipating what type of pitch might be thrown, and to what location. Williams' approach to selective and strategic hitting has been highly influential in the modern game of baseball (Verducci, 2000).

Strategic decision-making has a role in pitch recognition in that it enables the batter to reduce the alternatives, lowering the cognitive load and "priming" the recognition decision (Paull & Glencross, 1997). Sports science researchers have found that pre-pitch information does improve batters' ability to predict pitch location (Gray, 2002). However, strategic (pre-pitch) decision-making is not the same a perceptual decision-making (see Fadde, 2002 for a complete task analysis of pitch recognition). They are entirely different cognitive processes that suggest different training approaches.

Domain of Perceptual Decision-Making

Perceptual decision-making is not a physiological attribute of vision. Such attributes as dynamic tracking acuity and peripheral vision have been shown by sports science research to *not* be primarily responsible for expert-novice differences (Chamberlain & Coehlo, 1993). Sports scientists taking a cognitive information processing (CIP) view of perceptual decision-making have studied it using the expert-novice paradigm. The classic CIP expert-novice chess studies (Simon & Chase, 1973) showed that chess masters do not posses prodigious memory for random placement of chess pieces on a board but rather context-specific schema that enable them to remember meaningful arrangements of chess pieces. Sports scientists using expert-novice studies of reactive sports skills have come to the same conclusion, that the experts' advantage is a *software* rather than a *hardware* advantage (Chamberlain & Coehlo, 1993).

Although it is associated with psychomotor performance, PDM is a distinctly cognitive process. However, as described above, PDM is different from strategic, rule-based decision-making. Classic theories of optimal decision-making involve assessing all alternatives and predicting the likelihood of their success. This isn't possible in contexts of extremely limited information and time (Gonzalez, Lerch, & Lebiere, 2003). So, while there are considerable bodies of psychology research on both perception and decision-making, neither applies to the domain of perceptual decision-making.

PDM isn't a skill that is taught – like riding a bicycle – so much as it is trained; in the same way that strength training is used to develop specific muscle groups. As with "math facts", the goal of PDM training is to build automatic stimulus-and-response associations rather than to learn conscious calculations. The appropriate instructional method to develop automatic associations is drill and practice (Alessi & Trollip, 2001).

Pitch Recognition Research

Sports science researchers focusing on understanding perceptual decision-making have used film/video-based tasks to measure the target skill. The visual display is cut off at various points during the opponent's action and resulting ball flight. Experts generally make more accurate and faster predictions, especially when viewing drastically restricted display. In baseball, Paull and Glencross (1997) found that players in the top-grade Australian professional baseball league (experts) were superior to lower-grade professional players (novices) in their ability to identify the type of pitch and predict its ultimate location over the plate. Complementing the body of expert-novice research is a smaller body of training-based studies (all training baseball pitch recognition or tennis serve recognition) that show that perceptual decision-making skills can be improved through temporal occlusion training (Farrow, 1998).

The key question is whether laboratory-measured training gains transfer to psychomotor performance of the skill. Burroughs (1984) trained college baseball players using film-occlusion and then measured their performance in a live test that duplicated the laboratory task. Burroughs devised the Visual

Interruption System (V.I.S.) – a specially designed batting helmet with a face shield that dropped in front of the batter's eyes shortly after the pitcher released the ball. The players in the film-occlusion training group were better able to identify pitch type and predict pitch location in the V.I.S. live occlusion task. Burroughs' V.I.S. test demonstrated near transfer of the cognitive sub-skill of pitch recognition from the mediated training task to a live testing task.

Another aspect of transfer-of-learning was measured by studies (e.g., Farrow et al., 1998) that used occluded video of novel servers to assess the effects of video-based serve recognition training. Scott, Scott, and Howe (1998) extended the transfer-of-learning question by using a live performance-based testing task. The testing task, which was used as a pre and post-test, involved subjects returning serves on court. A scoring formula was used that valued the recognition aspect of serve return over the execution of the return. The change scores on the performance-based task from pre to post-test were used as a measure of the effects of video-based occlusion training.

Only a few PDM training-based studies have been conducted. However, the results suggest that effects of film/video-occlusion training: 1) transferred to a video-occlusion test using novel opponents (Farrow et al., 1998), 2) transferred to a live occlusion task (Burroughs, 1984), and 3) transferred to a live, performance-based task (Scott, Scott, & Howe, 1998). The study reported here expands the transfer-of-learning question by measuring effects of video-occlusion training of pitch recognition in terms of game-batting performance.

TRAINING METHODS

Repurposing Sports Science Research for Training

The design of the interactive video-baseball (IAV-BB) pitch-recognition training program was based on techniques developed by sports scientists to research the differences between "experts" and "novices" in perceptual decision-making tasks such as pitch recognition. Sports science researchers investigating PDM have developed film/video occlusion techniques for describing when (temporal occlusion) and where (spatial occlusion) the expert is "seeing" information that the novice is not. Spatial occlusion tasks, in which portions of the video display are masked, have provided little meaningful information beyond observing that expert batters concentrate more intently on the pitcher's release point (Shank & Haywood, 1987).

The temporal occlusion studies have been more valuable for isolating the points in time where experts pick up usable information. Paull and Glencross (1997) found that the difference between experts and novices lessened when more than about a third of the ball flight of the pitch was shown. Conversely, there were small differences between experts and novices at occlusion points prior to the moment-of-release of the pitch. Training in pitch recognition should therefore be focused on the time between the release of the pitch and approximately 1/3rd of the ball's flight. Other sports have a different window of expert perceptual advantage.

The video for IAV-BB was shot and edited in the same way that it was for laboratory research film/video occlusion tasks. Four pitchers were videotaped from the point of view of a batter (both left-handed and right-handed batters' points of view). The clips were edited to show different amounts of ball flight. Data associated with each clip indicated the type of pitch and the location of the pitch in a nine-cell strike zone.

Each pitch was edited into clips of three different lengths. The most difficult version of each pitch cuts to black immediately after the ball leaves the pitcher's hand – the moment of release (MOR). Mid-level difficulty is represented by clips cut off at two frames of video after the pitch is released (MOR+2). The easiest clip shows five frames of video after the release of the pitch (MOR+5). Referencing the NTSC video standard of 30 frames of video per second, a single frame represents 33 milliseconds. MOR+2 therefore shows 67 milliseconds of ball flight while MOR+5 shows 165 milliseconds of ball flight – the outer time limit suggested by the expert-novice study of Paull and Glencross (1997).

While the video clips were prepared in the same way, there are differences between using the temporal occlusion task for research (testing) purposes and for training purposes. The question is: What needs to be done with film/video occlusion testing tasks in order to create effective interactive video drill and practice training tasks? As suggested by Alessi and Trollip (2001), the essential elements of the drill and practice instructional method are repetition and immediate feedback. Other instructional design elements that contribute to "repurposing" a testing task for training purposes are progressive difficulty and instructional content. Table 1 shows how these elements are used differently for testing purposes and for training purposes.

TABLE 1
Instructional elements used differently for testing and training.

Element	Testing Purpose	Training Purpose
Repetition	Minimum to measure skill	As needed to develop skill
Feedback	None	Immediate and corrective
Difficulty	Mixed to avoid training	Progressive for mastery
Instruction	None	Initial and remedial

Repetition. For research purposes, the goal is to use the minimum number of repetitions to assure that the state of the participants ability is thoroughly tested, but not affected. With training purposes in mind, the goal of drill and practice method is to provide massed repetition in order to increase speed and accuracy of cognitive or psychomotor skills to a mastery level. One of the primary attributes of mediated instruction is the ability to organize and present many more repetitions than is possible with “live” practice. Scott, Scott, and Howe (1998) gave as many as 120 ten-minute training sessions to each of the six participants they trained in tennis return-of-serve recognition.

Feedback. Ericsson, Krampe, and Tesch-Romer (1993) in their influential article on the role of deliberate practice in the development of expertise noted that repeated exposure to a task does not ensure that the highest levels of performance will be attained. Immediate and corrective feedback is another essential building block of a drill and practice training program (Alessi & Trollip, 2001). In the occlusion tasks used to test PDM ability, subjects are never given immediate feedback on their predictions. To do so would undermine the testing goal of the research. All of the training-based perceptual decision-making studies, on the other hand, included immediate and corrective feedback as a basic instructional element.

Progressive Difficulty. In most sports expertise studies the occlusion conditions range in difficulty from a full view of the opponent’s action and resulting ball flight to a view in which the action is cut off before the ball is thrown or struck. In expertise research designs, presentation of items of varying difficulty is mixed to measure the participant’s perceptual decision-making ability in different occlusion conditions while avoiding potential training effects. With the goal shifting from testing to training, the design systematically uses different occlusion points to create progressive difficulty. This permits a mastery approach to learning in which achieving a criterion score at one level of difficulty moves the learner to the next level of difficult. The element of progressive difficulty is familiar to athletes in the context of physical conditioning and strength training. In a similar way, but in a different domain, repetition and progressive difficulty work together to let athletes not only learn but *condition* perceptual decision-making abilities.

Instruction. The provision of instruction is another element that can be added to video-based occlusion tasks in order to re-purpose the tasks from testing goals to training goals.

The question with PDM training is what instruction to give. The cognitive processes involved in PDM are parallel, rapid, and largely unconscious. As a result, PDM skills like pitch recognition defy analysis using traditional self-report data collection techniques like reflective interview and think-aloud protocol (Abernethy, Thomas, & Thomas, 1993). Some studies have used psycho-physiological measures such as electroencephalographic (EEG) data, to confirm the existence of cognitive processes and pinpoint the time frame in which the target processing occurs (Radlo et al., 2001). While psycho-physiological measures refine the *where* and the *when* of expert PDM, they do not access *what* experts are seeing.

A review of baseball coaching literature (see Fadde, 2002 for full review) found little systematic analysis of pitch recognition but did produce a number of “tips” that expert batters use in recognizing pitches. For example, a number of major leaguers report seeing a quarter-sized “hole” in the ball that identifies a slider (Baker, Mercer, & Bittinger, 1993). Others report picking up the “thin wrist” of a pitcher throwing a curveball (Moneleone & Gola, 1997). However, there is considerable disagreement among expert hitters in regard to seeing spin (Maza, 1999) and other aspects of pitch recognition.

Not only are expert batters generally unreliable in describing their thought processes during PDM but also are unable to describe how they developed this elusive skill. So where does that leave the question of how to teach a PDM skill like pitch recognition? Expert batters clearly do not need to be consciously aware of the cognitive process that they use to recognize pitches, so it’s logical to assume that near-expert batters do not need to be explicitly taught PDM skills. What is known is that expert batters are able to recognize video representations of pitches earlier in the ball flight. The goal of PDM instruction, then, is to reproduce that ability in learners.

While sports science research has not succeeded in describing the process of PDM, it has provided direction on how to train the skill. Paull and Glencross in their definitive 1997 expert-novice study of pitch recognition ran separate experiments to measure the ability of experts and novices to identify pitches and to predict their location. They determined that experts are able to identify the type of pitch at occlusion points as early as moment-of-release (MOR) but need more ball flight to predict the eventual location of the pitch in the strike zone. Tennis return-of-serve studies have also differentiated identifying the type of serve and predicting the location of the serve (Scott, Scott, & Howe, 1998; Singer et al., 1994). The research suggests a training approach in which *type identification* and *location prediction* are treated as separate and serial components of the pitch recognition skill. Separating type identification and location prediction into PDM sub-skills and adding the element of progressive difficulty from easier to more difficult occlusion points provided a "curriculum" for pitch recognition training.

Interactive Video Pitch Recognition Training Drills

Each baseball player in the interactive video pitch-recognition (IAV-BB) training group individually received nine ten-minute interactive video sessions. In each session the player viewed a 45"-inch rear projection video screen that showed a pitcher delivering a pitch (see Figure 1). A training facilitator (the researcher) performed all of the interactive instructional management tasks that have since been programmed into a computer-controlled application. The facilitator introduced each drill, played the appropriate sequence of video pitches, recorded the player's verbal input of pitch type and/or location, gave the player immediate corrective feedback, and provided a summary score at the end of each drill.

Specific IAV-BB drills were developed to isolate and train particular aspects of the pitch recognition skill. Drills focused on Pitch Type Only, Pitch Location Only (known type), and Combined Type/Location. As indicated by Paull and Glencross (1997), identifying the type of pitch being thrown is the first cognitive operation in the perceptual decision-making process of pitch recognition. Information on the type of pitch is then combined with early ball flight information to generate a prediction of when and where the pitch will enter the hitting zone.

IAV-BB training started with Pitch Type drills. Subjects started by identifying pitches that were occluded at MOR+5, that is, five frames of video after the moment-of-release of the pitch (approximately 165 ms).

FIGURE 1
Interactive Video training.

When that level of difficulty was mastered the participant progressed to Pitch Type: MOR+2 (67 ms), and eventually to Pitch Type: MOR, which showed no ball flight. The second IAV-BB drill involved predicting the location in the strike zone of known types of pitches. Players were shown sets of pitches sorted by type: all fastballs, all curveballs, all sliders, etc. Pitch Location drills involved predicting the ultimate location of each pitch in a nine-cell strike zone grid. Mastery of the Pitch Location drill at MOR+5 led to attempting the drill at MOR+2. Pitch Location drill did not use the MOR occlusion condition because experts (Paull & Glencross, 1997) required some ball flight to be able to predict location.

IAV-BB training attempted to use a combined Pitch Type Plus Location drill but the amount of input and feedback information was too much for the facilitator to handle and the drill was abandoned midway through training. Interestingly, when Pitch Type Plus Location was used, subjects who had established a high score on Pitch Type drill degenerated considerably when instructed to identify type first and then predict location. This is consistent with cognitive load theories.

RESEARCH DESIGN

The experimental design was that of Untreated Control with Posttest Only (Cook & Campbell, 1979). The primary research question was: Does mediated training in the cognitive skill of pitch recognition transfer to performance of the full psychomotor skill of batting? Secondary research questions dealt with learner satisfaction with the IAV-BB implementation: Do advanced baseball players accept video-based training as realistic and valuable? How do players view different drills (type/location/both)?

Participants

The pool of participants consisted of all of the position players on the cooperating NCAA Division I college baseball team who signed a consent form indicating their willingness to participate in the project. Before training was implemented the team's coaches ranked the batters on the basis of overall hitting ability. Adjacently ranked hitters were matched in pairs. In each pair one batter was randomly assigned to the treatment group. The other player in each matched pair was assigned to the control group. The technique of matching before random assignment allowed for the creation of a control group that was similar to the experimental group while also providing the benefits of random assignment (Cook & Campbell, 1979).

IAV-BB training was done over the course of two weeks during the team's normal pre-season practice sessions. In this way the players in the training group were not asked to contribute time beyond team practice, avoiding any potential for violating NCAA policies that limit the practice time of student athletes. Subjects were informed that they could withdraw at any point in the study for any reason.

Data Sources

The effect of mediated pitch recognition training on batting performance was measured by game batting statistics from a posttest period of eighteen games. The posttest period consisted of the games played after the IAV-BB training and before the start of the team's conference schedule. The statistics used are commonly calculated in baseball: Batting Average, On-Base Percentage, and Slugging Percentage. The participating university's sports information department calculated the statistics. Batting Average divides base hits by at-bats (not counting bases-on-balls and sacrifices). On-Base Percentage includes bases-on-balls in both the numerator and the denominator. Slugging Percentage divides total bases resulting from hits (not counting bases-on-balls) by at-bats. Batting Average has long been the standard statistic for measuring batting performance (Hernandez & Bryan, 1994) while the other two statistics are considered to emphasize different aspects of hitting performance.

The statistical significance of differences between control and treatment groups on hitting performance measures was determined by ranking all of the participants, both treatment and control, and applying the Mann-Whitney *U*-test, scaled for small *n* analysis. This technique was used in an expert-novice study involving perceptual skills in table tennis (Ripoll & Latiri, 1997).

In addition to the quantitative data measuring batting performance, each player in the treatment group filled out a questionnaire after the final IAV-BB training session that focused on learner satisfaction. Players made written comments on the drills and the video training in general. The subjects used a scale of 1 (low) to 5 (high) to rate each of the IAV-BB drills. The players were asked to rate the drills on the basis of value. The players were also asked to rate the realism of the video display.

RESULTS

Game Batting Statistics

Figure 2 presents game hitting statistics from the team's 18-game pre-conference schedule (used as the post-training test).

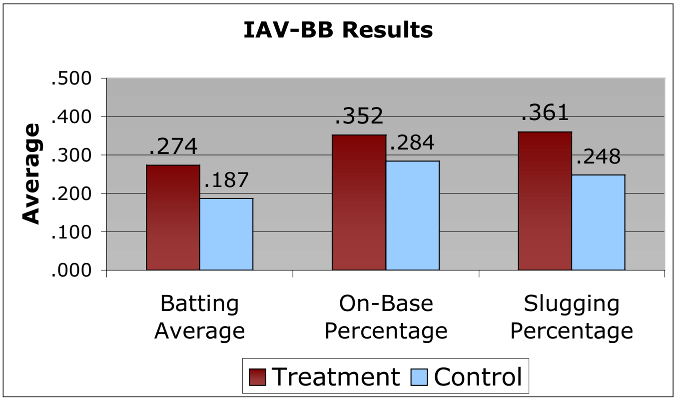

FIGURE 2
Post-Training Batting Statistics.

The batting statistics are presented because they are familiar to baseball coaches and players and are accepted as measures of batting performance. However, there are statistical problems with using *group* summary batting statistics. The question of statistical significance of differences between treatment and control participants was addressed using the Mann-Whitney *U*-test (see Figures 3a, 3b, 3c), which references the ranks to treatment and control subjects within the total pool of participants.

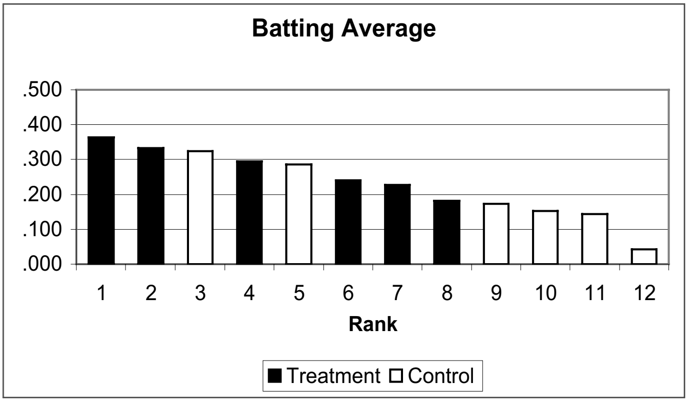

FIGURE 3a
Batting Average rank, *p=.047*.

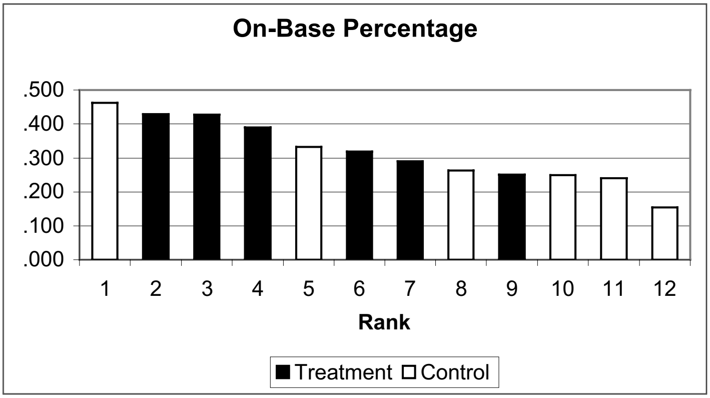

FIGURE 3b
On-Base Percentage rank, *p=.120*.

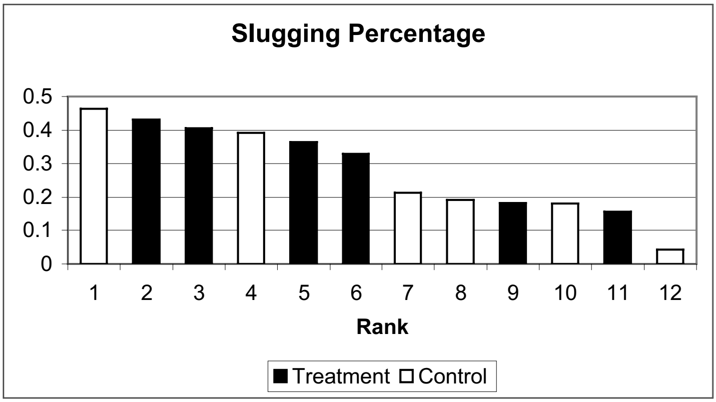

FIGURE 3c
Slugging Percentage rank, *p=.155*.

There are clearly observable "face value" differences between the treatment and control groups on all three batting measures (see Figure 2). The statistical significance of these differences is addressed using the Mann-Whitney *U*-test. The measure of Batting Average indicates a statistically significant difference (*p<. 05*) between treatment and control groups over the post-test period. The differences between treatment and control groups on the measures of On-Base Percentage and Slugging Percentage were not significant.

It is highly unusual to observe a significant effect of a training implementation on game performance. I do not want to overstate the finding of a significant effect of training on one of the game-batting measures without replication in other studies. This is the first reported use of game statistics as a measure of the effect of PDM training on psychomotor performance of the full skill and the finding of a statistically significant effect on a measure of competitive performance is potentially very meaningful.

Post-Training Questionnaire

The players in the treatment group appeared to accept the realism of video pitches on the basis of their ratings (4.1 on 5-point scale) and comments. In an expert-novice study that involved point-of-view video of a baseball pitcher, the video display was considered by the researchers to be adequately realistic based on a player-generated rating of 6.6 on a ten-point scale (Shank & Haywood, 1987). Players valued the Type Only (4.5) drills more than the Location Only (3.1) and Type Plus Location (3.6) drills. Results of the questionnaire are offered for descriptive value and are not analyzed as data.

TABLE 2
Player satisfaction questionnaire - IAV-BB drills.

Drill	Rating (mean)	Comments
Type Only	4.5	• This made me look for keys in his arm motion to recognize pitches early. • Very productive drill. It helped me pick up on more things to look for (hands, skinny wrist). • Helps to read ball out of hand.
Location Only (know pitch type)	3.1	• I didn't like this much because curveballs left the screen early and were more guess work. • Some of the locations I thought were a little messed up. • Location was a little difficult. Hard to visualize the whole distance.
Type + Location	3.6	• A little harder to recognize both at the same time. • Really had to focus on this one! A great tool. • This drill was good because the opportunity to call pitch type as well as location gave a feel of realistic batting situations.
Realism of video pitches	4.1	• I think that there needed to be a larger frame especially for curveballs, and see if you could center the strike zone better. • Pitches seemed relatively realistic. • As good and realistic as a video can be. • I was surprised that it did appear very realistic and helpful.

DISCUSSION

The finding that treatment players ranked higher than control players on posttest measures of game hitting performance suggests that interactive video was an effective way for near-expert batters to improve the pitch recognition skills that have been recognized by sports science as a key difference between expert and novice performers. Interactive video training based on sports science research provides athletes and coaches with an approach for developing an aspect of expert-level performance that is generally conceded to result only from instinct or massed experience.

In addition, perceptual decision-making being in a domain of learning that can be addressed with mediated instruction gives an athlete seeking the expert level an opportunity for training and practice outside of the already exhausted psychomotor domain. Systematic training of perceptual decision-making aspects of complex sports skills has the potential to accelerate the ten-year rule of developing expertise (Ericsson et al., 1993), helping more athletes to reach expert-level performance in less time.

The IAV-BB training implementation validates the cognitive information-processing (CIP) model of perceptual decision-making by decoupling the cognitive component of a complex psychomotor skill, addressing that cognitive component with mediated training, and then re-coupling the cognitive and motor components to improve performance of the full skill. While supporters of an ecological approach can fairly criticize occlusion-based expert-novice studies for breaking the perception-action link (Bootsma & Hardy, 1997), the players' acceptance of the mediated training and the performance improvement associated with the IAV-BB pitch-recognition training supports the CIP model.

Application of PDM Training Beyond Sports

Current trends in training technology and research focus on enhanced realism in Virtual Reality and video game environments. While it is important to "push the envelope" with such developments it is also important to ask questions directed at discovering the best combinations of instructional technologies and methods to maximize instructional effectiveness and efficiency. That includes investigating lower-tech solutions that may be able to address specific learning goals.

This study suggests that technically modest interactive video training may be not only adequate but optimal for developing perceptual decision-making ability in sports and potentially in other skill areas. Areas of performance that include a substantial perceptual decision-making component include use-of-force, emergency response, security, and vehicle operation. Each of these areas involves extremely rapid decision-making based on limited and changing perceptual information. These skill areas are similar to sports performance in that PDM is closely tied to psychomotor actions. The key question is if the perception-link can be broken for the sake of focused training of the PDM component. The point of de-coupling domains of learning is that training that targets a cognitive component of a complex skill can be produced much less expensively than highly realistic simulator-type training that targets the whole psychomotor skill.

In use-of-force training for police and military, trainees must master a sequence of situation recognition/response selection/response execution that has life and death consequences. Police officers or soldiers who make slow decisions can be shot, while making a fast but inaccurate decision can result in the shooting of innocents. As with training of airline pilots, the high cost of mistakes in the field justifies high-cost training that often includes high-fidelity simulators such as those used by the Los Angeles Police Department (McMahon, 1999).

While high fidelity simulator training is thought to be effective, it is not efficient, as trainees must leave the field to go to the site of the simulator. With many officers to train in limited time and with limited simulator stations, it is improbable that a trainee can spend the hours needed to build the "trained reaction" that is the presumed training goal. If trainees were able to engage a PDM use-of-force training program on a laptop computer – which could be used on the trainees' own time or even in the field – it should reduce the amount or increase the effectiveness of the much more expensive simulator training time. The U.S. Navy has recognized the training value of "micro-simulations" and has started issuing a customized version of Microsoft's *Flight Simulator* software to student pilots enrolled in Naval Reserve officer training courses (Macedonia, 2002).

The goal of lower overhead training of PDM is not to replace higher overhead training of the full skill in the form of live training or high fidelity simulation. As is often the case with alternate instructional technologies, the question is not one of *supplanting* current methods but of *supplementing* current training techniques (Winkler & Polich, 1990). The approach suggested in this paper offers a way to target an elusive and essential aspect of expert performance that is usually considered "un-trainable" and to develop it systematically and efficiently using modest instructional technology.

Recommendations for Further Research

Two directions for further research and training are to apply the findings and techniques that have been developed in baseball (pitch recognition) and tennis (serve recognition) to other sports skills and to non-sports areas of performance that involve a significant level of perceptual decision-making. This study suggests that training applications based on sports science research should: 1) isolate PDM aspects of the overall skill for training (after a thorough task analysis), 2) use the instructional technology of interactive video technology and the instructional method of drill and practice, and 3) adapt existing performance measures or create performance-based tasks to evaluate the effects of training.

The hope is that future research involving video-based training of perceptual decision-making will go beyond the question of "does it work" too look at "how does it work best." This involves isolating specific aspects of instructional design or learning theory to serve as independent variables. Chief among these variables are *fidelity* of display, input, and feedback. These factors determine the amount and type of realism that is required in a training environment. The assumption that more realism means better learning should constantly be challenged.

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