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DEVELOPMENT ARTICLE

Instructional design for advanced learners: training recognition skills to hasten expertise

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Abstract Expertise in domains ranging from sports to surgery involves a process of recognition-primed decision-making (RPD) in which experts make rapid, intuitive decisions based on recognizing critical features of dynamic performance situations. While the development of expert RPD is assumed to require years of domain experience, the transition from competence to expertise may potentially be hastened by training that specifically targets the *recognition* aspect of RPD. This article describes a recognition training approach that is based on expertise theories, research findings, and laboratory measurement techniques. This approach repurposes laboratory research tasks as deliberate practice training tasks. Although pioneered in sports expertise research, this approach is appropriate for pre-service and in-service professionals in a wide range of domains that involve rapid, recognition-primed decision-making.

Keywords Advanced learning · Expertise · Instructional design · Performance · Recognition-primed decision-making · Training

Introduction

This article follows up on a challenge by van Gog, Ericsson, Rikers, and Paas (2005) for instructional designers to apply theories of learning and instruction to devising instructional methods and activities intended for advanced learners. Historically, the instructional design field has been both focused on and effective in directing novice and intermediate learners' acquisition of declarative knowledge and skill competence. Now, with the continuing evolution of theories of expertise and expert performance—as highlighted by

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publication of *The Cambridge Handbook of Expertise and Expert Performance*[1] (Ericsson, Charness, Feltovich, & Hoffman, 2006)—the time appears ripe for combining the efforts of the historically distinct fields of primarily descriptive expertise research and primarily prescriptive instructional systems design in order to devise strategies for hastening the transition of advanced learners to expert performers.

This article focuses on a particular type of expert performance that requires a rapid sequence of recognition, decision, and action—performances that involve *reaction* skills. Reaction performance skills are differentiated from deliberate and controlled action performance skills. In the sports realm, action skills include hitting a golf shot and executing a gymnastics vault while reaction skills include goalie play in hockey or soccer, batting in baseball, and return of serve in tennis. Many performance activities include both action and reaction skills and often they are performed almost simultaneously. A classroom teacher, for example, is engaging in action skills in delivering a planned lesson while also engaging in reaction skills in managing the classroom and monitoring students' comprehension. Inexperienced teachers often experience excessive cognitive load in monitoring student behavior and comprehension that can adversely affect delivery of the lesson (Feldon, in press). However, while it is common practice in training and education programs to focus instructional attention on action portions of performance, the reaction component is seldom directly practiced. Yet it is the natural and effortless execution of reaction skills that often typifies expert performance.

This article draws on expertise theory, especially the theoretical model of *recognition-primed decision-making* (RPD), in order to outline an approach to hastening learners' development of expertise in reaction performance skills. Special attention is given to sports expertise studies that have adapted the laboratory measurement techniques developed by expertise researchers in order to create recognition training programs. It is a central premise of this article that the challenge of designing representative tasks to train expert recognition skills can be met in part by *repurposing* the types of tasks designed to measure expertise in the laboratory. Studies that have used this approach to enhance expert recognition skills in sports have evolved a low fidelity form of simulation that has implications for training complex psychomotor skills in domains such as aviation and surgery where high fidelity simulation is routinely used. The recognition training approach that is described in this article also has applicability in improving more cognitively oriented skills such as medical diagnosis, security screening, physics problem solving, classroom teaching, and social services interviewing.

This article has three parts. In the first part, theories of expertise and expert performance are reviewed. The second part explains targeting recognition skills for expertise training. The third part of the article outlines a four-step approach for developing recognition training programs that can potentially be applied in a wide range of skill areas.

This recognition training approach is presented with a number of qualifications. The first is that it is generally not appropriate to apply expert schema induction to initial learning by novices. Recognition training does not replace direct instruction in rules, concepts, and procedures but rather enhances it...at the appropriate time in the learner's development. Another qualification is that, while some of the domains discussed have an existing body of expertise research to draw on, instructional designers in many domains are not as fortunate.

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[1] While numerous edited volumes and special journal issues have marked the evolution of a distinct theory of expertise and expert performance, the publication of *The Cambridge Handbook of Expertise and Expert Performance* can be considered watershed. The volume contains seminal theory contributions as well as articles reporting expertise research in a surprisingly wide range of domains. Some of the articles in the *Handbook* that are cited in this article reference earlier works by the same authors. In most of these cases, the *Handbook* article is cited here rather than the original article.

Developing expertise training in these domains often requires studying expert performance by using techniques such as cognitive task analysis. A third qualification is that there is little agreement on definitions of *expert* or *expertise* within specific domains. Experts are sometimes defined in terms of amount of experience (e.g., years in the field or flight hours), status, professional certification, or recognition of peers. Seldom is expertise measured by performance on representative tasks, and when it is, experts often perform no better than non-experts (van Gog et al., 2005). That could mean that the identified ''experts'' are not truly expert, or it could mean that the tasks are not truly representative. The question of ''what is an expert?'' is somewhat skirted when training, rather than describing, expertise because the goal of moving individual learners along a continuum from less expert to more expert reflects a relative rather than an absolute view of expertise (Chi, 2006a).

The recognition training approach that is described in this article targets advanced learners and practitioners who are on a clear trajectory to expertise. That includes trainees who are near the completion of formal training programs (e.g., police, military, emergency response) and students finishing professional education programs (e.g., medical, nursing, teacher preparation), as well as in-service professionals who are poised to transition from journeyman to expert status.[2] Experience, of course, is essential in the development of expertise. A tenant of the theory of expert performance is the *ten-year rule*, which posits that approximately ten years and 10,000 h of deliberate practice—consisting of purposeful activities intended to improve specific skills—are necessary (but not sufficient) to become an expert performer in a variety of domains (Ericsson, Krampe, & Tesch-Römer, 1993). Typically, the ten-year time frame encompasses both preparatory and professional stages of a performer's career. As an air traffic control instructor put it, ''after about seven years in the field some of our students become recognizable experts. Others are just seven years older (K. Gannell, personal communication, August 16, 2004).''

Expert performance obviously has many facets and expertise takes many years to develop, often involving centuries-old methods for transferring knowledge and gaining experience. The relatively modest instructional goal of hastening the development of expertise leads instructional designers to seek opportunities to improve on the established processes. Since the acquisition of knowledge and skills are adequately addressed by traditional education and training programs and domain experience is largely outside the realm of instructional design, an opportunity comes in targeting an aspect of expertise that is not typically addressed by direct instruction—the intuitive or recognition-primed decision-making that typifies expertise in many domains.

Expertise theory and research

Recognition-primed decision-making

An air-traffic controller spots something unusual on the computer screen and instructs a pilot to immediately drop one altitude layer, avoiding a close encounter with another plane.

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[2] Based on Hoffman (1998), Chi describes a guild-like proficiency scale that progresses from novice to initiate to apprentice to journeyman to expert to master. Journeyman is defined as ''Literally a person who can perform a days labor unsupervised, although working under orders. An experienced and reliable worker, or one who has achieved a level of competence. Despite high levels of motivation, it is possible to remain at this proficiency level for life.'' Expert is defined as ''The distinguished or brilliant journeyman, highly regarded by peers, whose judgments are uncommonly accurate and reliable, whose performance shows consummate skill and economy of effort, and who can deal effectively with certain types of rare or 'tough' cases'' (Chi, 2006a, pp. 22).

A football linebacker reads a screen pass and ‘‘blows it up’’ before the play can develop. A surgeon instructs an assistant to prepare for an arterial rupture, a moment before the rupture happens. A semi-truck driver brakes hard, but under control, to avoid rear-ending a merging school bus that was cut-off by a speeding car dodging into the merge lane. All of these scenarios involve experts making apparently intuitive decisions that involve quickly and naturally recognizing critical elements in the emerging situation.

Sometimes called intuitive decision-making or naturalistic decision-making, the ability to make complex decisions ‘‘in the blink of an eye’’ is recognized by both popular (Gladwell, 2005) and academic (e.g., Klein, 1998) writers as the ultimate expression of expertise in domains that require rapid decisions and actions. The concept is most clearly described as *recognition-primed decision-making* (RPD). RPD involves a sequence in which experts in a dynamic situation quickly recognize patterns, represent the situation as being of a particular type, notice any anomalies, spontaneously generate a solution, mentally rehearse the solution and, if acceptable, execute and monitor the solution. Which creates a new situation and recycles the sequence (Klein, 1998). RPD is distinct from traditional models of analytical decision-making in that it is less deliberate and much faster. RPD was developed to model the rapid, strategic command-and-control type of decision-making engaged in by intensive care nurses, tank commanders, and offshore drilling rig managers (Ross, Shafer, & Klein, 2006). In this article, RPD is extended to describe the type of on-the-ground, reactional decision-making that is displayed in the air-traffic control, football, surgery, and truck driving scenarios described above.

The expertise training approach that is outlined in this article targets the *recognition* aspect of recognition-primed decision-making for part-task training. The critical issues are 1) why to train recognition skills, 2) how to train recognition skills, and 3) if part-task training of recognition skills will lead to improved performance of the full skill. The question of transfer of training to performance is among the most challenging aspects of expertise research and training evaluation because on-the-job performance is notoriously difficult to measure. Indeed, one of the central reasons that sports provide a rich test bed for expertise research is that sports performance tends to be more observable and measurable than performance in other domains. A second transfer question is to what extent an expertise training approach developed largely in the sports realm transfers to other domains of expert performance. This question is addressed throughout this article by using examples, mostly hypothetical, drawn from a variety of domains.

Theory of expertise and expert performance

Although expertise has long been of interest to psychologists, philosophers, and educators, modern information-processing based theories of expertise have emerged in the wake of chess expertise research (de Groot, 1978; Simon & Chase, 1973). The chess studies introduced the expert–novice paradigm in which more expert performers are compared to less expert performers on a variety of tasks. In a classic expert–novice chess experiment participants were briefly shown an arrangement of pieces on a chessboard and then directed to duplicate the arrangement of pieces on another chessboard. When the chess pieces were randomly arranged, there was little difference in the ability of chess masters and lesser players to reproduce the original arrangement of pieces. However, when the pieces were arranged in meaningful patterns drawn from actual games, the chess masters were much better at reproducing the arrangement of pieces. The researchers concluded that chess experts use chess-specific schema to group pieces into meaningful chunks, thereby circumventing the generally accepted ‘‘seven plus or minus two’’ limitation of working memory (Miller, 1956). In the computer analogy adopted by the cognitive information-processing paradigm, expert chess players enjoy a software (schema) advantage rather than a hardware (memory) advantage. This observation has been essential to modern theories of expertise that emphasize learning and practice over innate talent and physiological attributes.

Expertise researchers have since investigated a variety of performance domains using the expert–novice approach[3] rooted in the classic chess studies. In sports, adoption of the expertise model led to a major paradigm shift in which perceptual skills previously attributed to physiological dimensions of vision such as dynamic tracking acuity and peripheral vision were instead attributed to skill-specific schema (Chamberlain & Coehlo, 1993). Even in an obviously psychomotor sports skill like hitting a pitched baseball, expertise research has revealed the distinctly cognitive sub-skill of pitch recognition as being the primary factor differentiating expert batters (Paull & Glencross, 1997).

Expert-novice studies in more obviously cognitive domains have also pointed to the recognition aspects of expert performance. In physics problem solving, for example, experts (graduate students) were able to more quickly and accurately categorize the type of problem being presented based on deep structure of the problem rather than on the surface features that novices (undergraduate students) used to sort problems (Chi, 2006b). In the area of medical diagnosis, researchers have found that more experienced clinicians rely more on non-analytical pattern-recognition to generate early hypotheses while less experienced residents rely more on analytical, rule-based approaches that relate symptoms to diseases (often embedded in narrative ‘‘illness scripts’’)—a strategy which experts also engage when a presenting problem defies initial recognition-based analysis (Norman, Eva, Brooks, & Hamstra, 2006). The question for medical educators is whether the development of expert-like, non-analytic, exemplar-based diagnostic reasoning can and should be accelerated through systematic training of pattern recognition skills.

Targeting recognition skills for expertise training

Two key training assumptions arise from research revealing expert–novice differences in recognition ability within complex skill performance. The first is that if recognition ability differentiates experts from near-experts, then enhancing the recognition ability of a developing expert should lead to enhanced expertise. Of course, superior recognition ability may be a product of and not a cause of expert performance. Still, it is worth exploring recognition training programs, in part because *recognition* is relatively easy to train, especially if trained separately from execution of a full recognition-decision-action sequence.

The second assumption of a recognition training approach is that the recognition-decision-action linkage in reaction performance skills can be de-coupled for targeted training purposes and then re-coupled for transfer to performance. This is not an uncontroversial assumption. Proponents of ecological psychology maintain that the linkage cannot be broken, either for descriptive purposes or training purposes, without essentially

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[3] Expert–novice research studies do not usually compare experts with true novices—which would make for a meaningless comparison. Instead, most studies compare highly skilled participants with advanced but less skilled participants. For example, Paull and Glencross (1997) compared Australian ‘‘A’’ League professional baseball players (experts) with Australian ‘‘B’’ League professional baseball players (novices). Although the expert–novice term is used, the area of primary research and training interest is the gap that separates competence from expertise.

changing the skill (Bootsma & Harvey, 1997). Without entering into a theoretical argument, the part-task training approach is—like Newtonian physics—a great way to build a bridge, even if it doesn't fully describe the universe of expertise. The bridge from expertise research to expertise training will be constructed in the section of this article that describes a four-step approach for training expert recognition skills. First, however, further consideration is given to why recognition skill is a particularly good target for expertise training.

Why train recognition skills?

With the instructional intent of hastening the development of recognition-primed decision-making, it is logical to start by targeting the recognition aspect of RPD for instructional attention. Recognition is not necessarily the most important part of the RPD process (which also includes solution generation, solution simulation, and solution monitoring), but it is the first part of the process and therefore provides a good instructional opportunity. Incremental improvement at the beginning of the RPD sequence should have an amplifying impact on the remainder of the process. In addition, the further up stream we go in an expert's RPD sequence the more complex and idiosyncratic the process becomes. The beginning of the RPD process is much more routine—what the 4C/ID instructional model calls the *recurrent* stage of problem solving (van Merriënboer, Clark, & de Croock, 2002).

Referencing another instructional design theory that has recently been applied to advanced learning, recognition training targets an aspect of performance that experts engage in with minimal cognitive load (van Gog et al., 2005). While cognitive load theory (CLT) has primarily been concerned with the role of cognitive load in instruction (e.g., multimedia design), CLT principles are increasingly being applied to considerations of cognitive load in *performance*. For experts, the recognition component of the RPD sequence requires little cognitive effort. Indeed, modeling recognition as *priming* decision-making suggests that the recognition stage is not actually part of the decision process but rather a distinct preparatory stage. Drawing on 4C/ID, cognitive load, and RPD models, low cognitive load in the preparatory recurrent stage of problem solving (recognition) frees cognitive capacity to be applied to the more conscious and demanding non-recurrent stage of problem solving.

The instructional implication of applying CLT to modeling and training RPD is that the recognition stage involves low cognitive load for experts because the concepts and rules underlying recognition skill are largely known and routine. The experts' advantage, as shown in numerous expert–novice studies in a variety of domains, is in the *speed* rather than the accuracy of recognition. Speed essentially becomes an operational representation of cognitive load. The advanced learner or practicing professional already possesses most of the requisite declarative knowledge and procedural skills; the instructional designer, teacher, or trainer is free to devise instructional activities intended to increase the speed of advanced learners' cognitive processing to approach that of experts. To quote cognitive psychologist J. R. Anderson (1980), ''One becomes an expert by making routine what to the novice requires creative problem-solving (Norman et al., 2006, p. 344).''

Recognition training focuses on the *ordinary* aspects of expert performance rather than the extraordinary aspects. Indeed, the argument can be made that expertise lies largely in ordinary performance. For instance, Endsley (2006) found that expert pilots did not make better decisions than novice pilots in simulation tests involving unusual or emergency situations. However, expert pilots were much faster at routine decisions and actions. In practice, since emergency situations usually evolve out of ordinary situations, the expert who handles the ordinary situations with low cognitive expenditure would be expected to have more cognitive resources in reserve for dealing with the emerging, novel situation.

How to train recognition skills

A critical challenge for instructional designers, as it is for expertise researchers, is to ‘‘identify those tasks that best capture the essence of expert performance in the corresponding domain, and then standardize representative tasks than can be presented to experts and novices (Feltovich, Prietula, & Ericsson, 2006, p. 49).’’ There are three components of this process. The first is to identify key skills within the target performance and the second is interpreting such skills or sub-skills in the form of standardized testing and/or training tasks that can be repeated and measured consistently in a laboratory context. The third component of creating representative testing/training tasks is to generate stimulus items to present to experts and novices in a research (testing) context or to near experts in a training context. The relationship between a representative task used for testing or training purposes is described in more detail in the section of this article that outlines a four-step approach for creating recognition training programs (see Table 1).

When the testing or training focus is on the recognition component of reaction performance skills, the designation of representative tasks is often clear. For instance, the recognition component of the complex psychomotor reaction skill of batting is *pitch recognition*. A quite different type of pitch recognition is involved in playing music—that is, a musician recognizing the notes being played by other musicians. Sight reading a musical score can also be considered to be a recognition skill that is performed with very low cognitive load by more expert musicians but that can create excessive cognitive load for less expert musicians. It is more challenging to partition the action and reaction skills in expert performance domains that don’t include an observable psychomotor action. For example, diagnostic-perceptual activities in the medical area involve reading an electrocardiogram (ECG), a mammogram, a radiograph (X-ray), or a microscope slide of a tissue sample (histology) or a blood sample (hematology). The action component may be considered to be stating a diagnostic decision. The reaction component, then, involves the pattern recognition sub-skill that *primes* the diagnostic action.

After a critical reaction performance skill is identified, the expertise researcher or trainer must then interpret the skill in the form of a repeatable and measurable task that can be used for testing and/or training purposes. Basic types of laboratory-based expertise testing tasks include: recall, detection, categorization (Chi, 2006b), and prediction (Endsley, 2006). Recall, detection, and categorization tasks can be considered to represent declarative knowledge level while a prediction task suggests knowledge advanced to the level of procedural knowledge (Anderson, 1982).

In some domains, expert–novice researchers have developed representative recognition testing tasks. Paull and Glencross (1997) represented the skill of pitch recognition in baseball as two separate tasks. Expert and novice baseball players were asked to *identify* the type of pitch being delivered by a pitcher shown on a video display (a categorization task). Participants were also asked to *predict* the ultimate location of the pitch in the hitting zone. Fadde (2006) added the instructional elements of immediate feedback and progressive difficulty to the pitch identification and location prediction tasks developed for expertise research in order to train pitch recognition skill in college baseball players.

The approach of repurposing testing tasks for training purposes can be applied in other areas as well. For example, Norman et al. (2006) report on a series of studies in dermatology that used a ‘‘clever’’ experimental design in which performance on a categorization task was assessed using typical-similar, typical-dissimilar, atypical-similar, and atypical-dissimilar slides of dermatological conditions. Assessing typicality was considered to represent more analytical reasoning while assessing similarity was considered to represent more non-analytical, pattern matching strategies. The study found that more experienced (and assumedly more expert) residents were better at recognizing similarity and medical students were better at assessing typicality. This experimental design can readily be repurposed as a recognition training task that is not only clever but is also validated in that it differentiates expert and novice performance. This four-way typicality-versus-similarity design supports creative instructional design. For example, the design of a dermatology diagnosis practice activity could be manipulated to increase the non-analytical reasoning ability of less experienced clinicians or to increase the analytical reasoning ability of practicing clinicians. This categorization task can likely be ported to training an array of medical perceptual-diagnostic skills. Indeed, the four-way typicality-versus-similarity categorization task may be adaptable to training recognition in diverse domains such as security screening and air-traffic control.

The typicality/similarity task provides a model of how well designed research tasks can be repurposed as training tasks. Research tasks must be reliable, valid, repeatable, and measurable—that is, standardized. Training tasks benefit from the same characteristics. In addition, testing tasks can sometimes be further optimized for training purposes because training tasks are less constrained by the requirements of research design and analysis. For example, expertise research designs that aspire to discover underlying cognitive mechanisms in expert decision processes often use non-authentic content in order to reduce previous knowledge as a confounding variable (Norman et al., 2006). Training designs, on the other hand, may purposefully elicit and integrate previous knowledge. Training activities should produce meaningful measurement of results, but not necessarily statistical analysis supporting generalizable findings.

While the approach of repurposing expert–novice laboratory research tasks to create recognition training tasks can be described hypothetically in reference to medical education and other domains, the approach has been developed, implemented, and researched in the area of sports science. Whether sports-based findings transfer to other psychomotor domains, and whether research on psychomotor skills transfers to more cognitively oriented problem-solving skills, are open questions. However, the potential for transfer is supported by sports expertise research being grounded in the same theory of expertise that underlies cognitive domains such as chess.

Repurposing sports expertise research for recognition training

Sports expertise researchers have been particularly active in the study of recognition ability—usually called perceptual-cognitive skills in the sports expertise literature (see Williams & Ward, 2003 for complete review). Numerous sports expertise studies have described perceptual-cognitive skills in a variety of sports skills as involving experts’ ability to pick up predictive information from cues that occur early in the movements of an opponent. A smaller body of sports expertise research has investigated whether such recognition skills can be trained. These researchers have pioneered the approach of repurposing laboratory techniques originally devised to measure recognition skills in order to train recognition skills. The key testing-to-training technique is *occlusion* in which portions of a visual display are masked.

Of particular interest are perceptual-cognitive training programs that used occlusion techniques to improve the pitch recognition ability of baseball players (Burroughs, 1984; Fadde, 2006) and the serve recognition ability of tennis players (e.g., Day, 1980; Farrow, Chivers, Hardingham, & Sacuse, 1998; Haskins, 1965; Scott, Scott, & Howe, 1998; Singer et al., 1994). The skills of pitch and serve recognition have been targeted for training because the opponent's pitch/serve action initiates every live play situation and because the pitch/serve comes from a set location at a set time, making it amenable to video-based simulation training. Arguably, the ballistic nature of pitch and serve recognition has few parallels in other domains of performance. However, the part-task training approach that entails de-coupling the recognition-decision-action components of a complex skill for targeted recognition training and then re-coupling to improve performance of the whole task could not be more dramatically demonstrated than in baseball batting and tennis service return, where the entire recognition-decision-action sequence happens in less than one-half second.

Recognition training design

In both research and training studies of pitch and serve recognition, participants viewed the projected film/video image of an opponent that depicted the internal point of view of a ''live'' participant. Researchers have used two types of occlusion (masking) techniques to study different aspects of expert recognition skill. Spatial occlusion involves masking different portions of the visual display of an opponent's action and then asking expert and novice participants to identify the type of pitch or serve. If the experts' advantage disappears when a particular portion of the visual display is masked, then it is assumed that the experts picked up predictive information from that particular portion of the display. Spatial occlusion techniques, often combined with eye tracking data, have helped researchers determine *where* experts are looking to attain their advantage in predictive ability. The findings of these studies have generally confirmed conventional coaching points such as concentrating on the pitcher's release point and watching the server's racquet and arm rather than the ball toss (Williams & Ward, 2003).

The other occlusion technique used for investigating expert recognition skill is *temporal occlusion* (time masking) in which the film/video display of an opponent's pitch or serve is edited to black at various points in the opponent's pitch or serve motion and resulting ball flight. The goal of temporal occlusion is to discover *when* experts and novices differ in their predictive ability. In baseball, expertise researchers have determined that the window of expert advantage is from the moment-of-release of the pitch through about one-third of ball flight (Paull & Glencross, 1997). The expert–novice difference is most exaggerated closest to the moment-of-release. At occlusion points prior to moment-of-release, the performance of both experts and novices is reduced to chance. After about one-third of ball flight, novices are as good as experts in picking up predictive information.

The pitch recognition training activity that is depicted in Fig. 1 is essentially the same temporal occlusion task that has been used in expert-novice pitch recognition research. The participant attempts to identify the type of pitch being thrown while viewing video display of an opponent pitcher, which is edited to black at various points in the delivery of the pitch or resulting ball flight. In the training program, learners progress from identifying pitch type while viewing video clips occluded after one-third of ball flight (which research showed that novices can do as well as experts can), to clips occluded closer to release of the pitch and ultimately to clips occluded at the moment-of-release of the pitch (which experts can do much better than novices). The critical assumption is that, *if* the learner is

Fig. 1 Video simulation training of baseball pitch recognition

competent in the necessary psychomotor skills of batting, then improving his pitch recognition ability to match the measured ability of expert batters should *hasten* the advanced learner’s progression to expertise in batting. As a major league baseball executive put it, ‘‘this is the difference between five o’clock hitters and seven o’clock hitters (F. Wren, personal communication, May 5, 2003)’’.[4]

The obvious question, then, is whether occlusion-based training can improve the cognitive sub-skill of pitch recognition and, further, whether improving the target sub-skill will lead to improved performance of the overall skill. A handful of pitch recognition training programs (Burroughs, 1984; Fadde 2006) have attempted to improve the pitch recognition ability of college baseball players. Importantly, the participants in both pitch recognition training programs verbally input their choice of pitch type or their prediction of pitch location and did not engage in a psychomotor action such as swinging a bat.

Participants in Burroughs’ study demonstrated near-transfer of performance gains from film-based pitch recognition training to a live pitch recognition task[5] Far-transfer of part-task, video-occlusion training to full-task in-game performance was demonstrated by participants in Fadde’s pitch-recognition training program. Half of a cooperating college baseball team’s position players (non-pitchers) received ten 15-minute individual video training sessions. Treatment and comparison groups were created using the method of matched pair with random assignment. The team’s coaches ranked the players according to perceived batting ability. Players who were adjacent in rank were then paired and randomly assigned to recognition training or traditional training (extra batting practice) groups. Treatment group players ranked higher than comparison group players (Mann-Whitney U-test) in the established batting performance measure of batting average ($P < .05$) over a post-training schedule of 18 games, as reported by official National Collegiate Athletic Association game statistics (Fadde, 2006).

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[4] Major league teams commonly play games about seven o’clock in the evening and take batting practice about two hours earlier. *All* professional baseball batters have the requisite physical and technical abilities to hit baseballs well in batting practice. Only the experts can do it consistently against major league pitchers under game conditions.

[5] Burroughs devised the Visual Interruption System (VIS) for creating occlusion conditions in a live batting task. The batter wore a batting helmet that was fitted with a shield that would drop in front of the batter’s eyes in response to an electronic signal. The signal was activated when the pitcher’s front foot landed on a force pad, an action that has a consistent relationship with the pitcher’s release of the pitch. Using the patented VIS system, the researcher could manipulate the interval between the signal from the force plate and the signal to the helmet shield, thereby creating variable occlusion points.

In other sports skills, the window of expert recognition advantage is different. Expert–novice studies involving serve recognition in tennis found that experts enjoy a perceptual advantage only at occlusion points prior to ball-racquet contact. This research finding informed the design of video-occlusion serve recognition training programs. For example, Scott et al. (1998) used only one occlusion condition—the moment of ball-racquet contact. All of the training video clips of an opponent's serve were edited to black immediately after contact. Progressive difficulty in the training program was achieved by starting with half-speed versions of the occluded video serves and progressing through a number of levels of progressively faster motion clips until learners could match experts' ability to identify serve type while viewing full-speed clips. Serve recognition training programs have been consistently successful in improving the target skill and have shown evidence of transfer of training effects from a lower fidelity training simulation environment to a higher fidelity simulation environment used to test serve recognition ability (Farrow et al., 1998). Sports science researchers, primarily working with the return-of-serve task, have also begun to investigate instructional design variables such as explicit instruction versus guided discovery that directs learners attention to information-rich portions of the display but does not specify what clues to look for (Williams, Ward, Knowles, & Smeeton, 2002).

Return-of-serve in tennis and batting in baseball—which Ted Williams called ''the most difficult thing in sport'' (Williams & Underwood, 1970, p. 7)—have few parallels in other domains of performance. There are non-sports skills, such as use-of-force decision-making by police or military personnel, which involve a similarly rapid recognition-decision-action sequence. However, these skills are not as contained and repeated as baseball batting and return of serve in which the initiating action of an opponent comes at a set time and from a set location. A lethal threat to a soldier or police officer can come in time frames and locations that differ with each situation. Still, the limited but consistent evidence that complex psychomotor skills such as batting and service return can be improved through training that targets the cognitive sub-skill of recognition using low-fidelity video-simulation (Starkes & Lindley, 1994) has potentially paradigm shifting implications for areas such as aviation and surgery where high fidelity simulation is commonly used but where excessive emphasis on physical fidelity can result in the ''wrong'' simulation being produced (Foshay, 2006). The full implications of this approach are that the recognition-primed decision-making process that is associated with the highest levels of intuitive expertise across many domains is amenable to training and that effective training approaches may be adequately, or even optimally, addressed using lower fidelity instructional approaches.

The following section codifies the discussion of recognition training while describing a four-step approach to designing, implementing, and evaluating recognition training programs that are intended to hasten the development of expertise in performance skills that involve recognition-primed decision-making. The four-step approach is presented as a beginning point for teachers and trainers, as well as instructional design researchers and practitioners, to consider if and how to develop recognition training programs.

Four-step recognition training approach

Designing, implementing, and evaluating a recognition training program involves:

1. Locating the recognition aspect of a reaction performance skill.
2. Devising tasks to test and/or train the recognition sub-skill.

3. Conducting a systematic recognition training program.
4. Enhancing and evaluating transfer of training using performance-based tasks.

Each step in the process is discussed in more detail below.

1) Locating the recognition aspect of a reaction performance skill. The value in differentiating action and reaction components of a performance skill is that they call for markedly different training approaches. In medical education, technical skills (e.g., surgery) are typically trained through classic demonstration and practice. Surgical training simulations are largely focused on procedural (action) skill acquisition. However, medical educators note that surgical expertise is not essentially a matter of technique but rather of anticipation (reaction skill) during surgery (Ericsson, 2004). Surgical simulations that include both the action and the reaction aspects of surgical performance become highly sophisticated. But when a part-task approach is taken, then simulations that focus solely on the action component can be as low in physical fidelity as practicing laparoscopic procedures by placing chick peas on golf tees in a minimal-access box trainer—as is done in the Royal College of Surgeons Basic Surgical Skills Course (Ward, Williams, & Hancock, 2006).

Part-task training of the reaction component of laparoscopic surgery could present learners with authentic video images recorded from the surgical micro-camera during actual laparoscopic procedures and ask them to pause the video if and when they detect a surgical misstep. This detection task, with immediate feedback, would address the most foreign aspect of laparoscopic surgery for practicing surgeons who were trained in traditional open surgery procedures—that is, learning to ‘‘read’’ the video image. As this example points out, the action component of complex skills is routinely de-coupled for targeted, lower fidelity training. Logically, the reaction component of a complex psychomotor skill can also be de-coupled for targeted, lower fidelity training.

Once the reaction performance skill domain has been identified, the instructional designer isolates the *recognition* component of the recognition-decision-action sequence through some form of cognitive task analysis (CTA). CTA has the goal of investigating expert knowledge, reasoning, and performance ‘‘in the wild’’ and leveraging that understanding into methods for training (Schraagen, 2006). While it is not always feasible for an instructional designer to carry out a full cognitive task analysis, it is important to analyze what experts think and do in addition to analyzing the concepts, rules, and procedures that traditional instructional systems design models focus on (Clark & Estes, 1996). Concepts, rules, and procedures are necessary and appropriate for initial learning and competence building. However, research has shown that as decision makers grow in experience they move from rule-based to instance-based decision-making (Gonzalez, Lerch, & Lebiere, 2003). The instructional designer can facilitate that transformation by providing the advancing learner with ample whole or part-task practice that includes repetition, immediate feedback, and progressive difficulty—the essential elements of multimedia drills (Alessi & Trollip, 2001) progressive difficulty.

2) Devising tasks to test and/or train the recognition sub-skill. The training approach that is described here *repurposes* the type of laboratory techniques developed to measure the recognition skills of experts and novices. Expertise researchers test recognition skills with laboratory tasks that are representative of the performance context but that are also repeatable and measurable—attributes of good training tasks as well as good testing tasks.

Table 1 illustrates the differences between similar tasks used for testing or training purposes. The primary differences are in the number of items used, the feedback provided, the sequencing of items, and the provision of instruction. Testing purposes are served by

Table 1 Instructional elements used differently for testing and training purposes

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

using the minimum number of items needed to measure the target skill whereas systematic training requires many more items. Immediate and corrective feedback is an essential element of training, but is not usually provided during a test—specifically to avoid a learning effect. In a test, items of varying difficulty are usually mixed while training often involves a progression of difficulty as the learner masters each level. Of course, content or skill instruction is not typically provided in a testing environment while initial or remedial instruction may be included in a training design.

A key contribution of sports expertise studies is the development of temporal occlusion as a powerful technique for testing and training recognition skills. While most performance domains do not require extremely rapid recognition, expert–novice research in chess, medical diagnosis, and other skill areas suggests that the differences between expert and novice recognition ability are exaggerated in speeded conditions (Ericsson, 2004). Increased speed in cognitive processes such as recognition can potentially serve as an indicator of reduced extraneous cognitive load, a key goal of recognition training.

Whether the target skill involves dynamic visual display (e.g., baseball pitch), or static display (e.g., X-ray), recognition skill can be tested or trained using occlusion tasks that involve displaying visual items in variably occluded or time-limited frames. The first step in creating an occlusion-based testing/training task is to create items (e.g., video pitches or X-rays). After items have been created a variety of tasks can be devised. Established laboratory tasks for testing recognition skill include recall, detection, categorization, and prediction. *Recall* tasks were common in early expertise research, such as the classic chess studies, but are used less because recall ability—although it differentiates experts and novices—is not usually part of the expert's cognitive process in performance (Ericsson, 2006). *Detection* tasks involve participants or trainees detecting the presence of a key piece of information in the visual display. *Categorization* tasks involve identifying critical elements of the display from a closed set of options (e.g., Pitch Type). *Prediction* tasks involve anticipating potential results. In a dynamic occlusion task, this can involve predicting the continuation of the action that was occluded (e.g., Pitch Location). A training design may use such tasks independently or in a performance-based sequence. Practice in reading mammograms, for example, would logically include a detection task of determining whether an item should be tagged for closer investigation—a realistic task when only 1–3% of mammograms detect malignancies (Ericsson, 2004). A separate categorization task might involve sorting potential malignancies by type.

Another key contribution of sports expertise training research is demonstrating that low fidelity, part-task recognition training is a potential alternative to high fidelity, full-task simulation training. The lower fidelity approach can be applied in other domains involving perceptual-cognitive skills. In the domain of truck driving, it is likely that—as with baseball batters—the difference between skilled and expert performers has little to do with requisite psychomotor skills. Once driving skills have been mastered, then a driver's progression in level of expertise is based largely on experience-based decision-making. However, a driver's experience may be limited to a particular type (over-the-road versus local) or location (urban east versus mountain west) of driving. If a company decided to systematically enhance the expertise of its drivers, it might develop a recognition training program that would artificially grow drivers' base of experience using a low fidelity ''video flashcard'' format that can be delivered over the Internet.

An instructional designer devising such a truck driving recognition training program can adopt research tasks that involve viewing a point-of-view computer display and pressing a button when a hazard is detected (Durso & Dattel, 2006). Additionally, Smith System (2006), a company that provides driver training for numerous trucking firms, instructs drivers to maintain a following distance of 7 s behind other vehicles and to look 15 s down the road in order to recognize potentially problematic driving situations. A recognition training program, therefore, might require drivers to view video display of items that depict an in-cab point of view of authentic driving situations and ask drivers to detect and categorize potential hazards in the 7–15 s window, and then to predict potential outcomes. These recognition training tasks should be validated by testing drivers of variable but known levels of expertise to see if the tasks in fact differentiate expert and less expert drivers.

3) Conducting a systematic recognition training program. Recognition training can be viewed as ''mental weight lifting'' in that it is not primarily directed at acquiring knowledge but rather at systematically strengthening a cognitive skill. As such, effective recognition training should entail a consistent and progressive program of activities rather than an occasional practice or testing activity. This type of expertise training program is potentially appropriate for an array of pre-service or in-service professionals in cognitive as well as psychomotor domains, such as radiology. While professional education programs for radiologists certainly involve viewing and judging large numbers of X-rays, traditional knowledge-building activities can be enhanced with systematic skill-building exercises that emphasize rapid recognition of critical X-ray features.

There may also be a continuing education role for recognition training of practicing radiologists. Ironically, while some experienced experts in radiology estimate that they will have analyzed more than half a million X-rays in their careers (Lesgold et al., 1988), practicing radiologists lack opportunities for *deliberate practice*—that is, practice with immediate feedback and focused learning goals. While practicing radiologists may receive feedback on their diagnoses, it tends to be far removed from the initial presentation of the X-ray, limiting the learning value of the feedback (Ericsson, 2004). In addition, there is the possibility that a radiologist working for years in the same or similar context may see limited types of X-rays—albeit a lot of them. The availability of deliberate practice opportunities that involve reading a wide variety of X-rays, with immediate feedback and progressive difficulty, could offer practicing radiologists an opportunity to expand their base of experience.

4) Enhancing and evaluating transfer of training using performance-based tasks. Some of the sports recognition training programs have been able to measure effects of recognition training on full-skill performance in a real-world context. However, directly measuring performance with accepted metrics is fairly unique to the realm of sports. A more useful approach is seen in the studies of recognition training programs that have shown transfer of recognition skills improved in video-simulation training environments to more elaborate and realistic simulation environments (Farrow et al., 1998). Sometimes called *pseudo-transfer* (Lee, Chamberlain, & Hodges, 2001), the technique of training using lower fidelity simulation and testing using higher fidelity simulation can be used to both evaluate and enhance transfer of training. For example, some smaller police departments rotate officers out of the field to train on the Los Angeles Police Department's high fidelity use-of-force simulator (McMahon, 1999). If police officers had access to lower fidelity recognition training on a laptop computer or over the Internet, officers might be able to reach proficiency in the recognition component of shoot-don't shoot decision-making and then use expensive high fidelity simulator training time to facilitate the transfer of recognition training to the full recognition-decision-action sequence and to certify a level of achieved performance.

Standardized and validated tests of domain expertise have a place in recognizing and rewarding expertise as well as in researching and training expert performance. Ericsson and Lehman (in van Gog et al., 2005) describe experts as showing ''consistently superior performance on a specified set of representative tasks for a domain (p. 277).'' Unfortunately, few domains have a set of representative tasks to measure expertise. Endsley (2006) has provided a model in devising a measure of situation awareness in aviation that she then used to test the decision-making of more experienced and less experienced pilots in a flight simulator. Endsley found that situation awareness was a better predictor of performance on simulation tasks than was flying hours. In the domain of commercial trucking, Allen and Tarr have developed a set of representative simulation scenarios, the *Virtual Check-Ride System*, that is used to test commercial truck drivers and that the researchers have also used to test the effectiveness of different truck-driving simulators (Allen & Tarr, 2005). With potential use in hiring, testing, training, certification, and promotion, the case can be made that expertise researchers, instructional designers, performance technologists, and industrial psychologists should invest in systematically devising representative tasks for a wide range of performance domains.

Discussion

One of the primary tenants of expertise theory is that experience, although necessary for the full flowering of expertise, is not the same as deliberate practice—and it is deliberate practice that is the single most important contributor to the development of expertise (Ericsson et al., 1993). With the exception of a few public performance domains such as sports and music, however, most professions do not have a ''culture of practice'' (Macmahon, Helsen, Starkes, & Weston, 2007). Rather, the development of expertise is accomplished through preparation for performance (mission rehearsal in military terms) along with post-performance debriefing and sharing of experience with other professionals, both formally and informally. While this process is effective in eventually developing expertise in many practitioners, the goal of *hastening* expertise calls for instructional designers to create efficient instructional tasks that target key cognitive skills such as recognition-primed decision-making.

The approach of creating training tasks by repurposing research testing tasks has been most fully developed in the area of sports but it can potentially be applied to professional education and in-service training in domains such as surgery, nursing, radiology, emergency response, aviation, air-traffic control, vehicle operation, security screening, crime scene investigation, classroom teaching, and use-of-force decision-making by police and military personnel. These are all domains that are, at times, addressed with simulation training (including ''live'' simulation such as student teaching). It may be that lower fidelity simulation that focuses on part-task training of the recognition aspect of recognition-primed decision-making can supplement, although not supplant, much more expensive high fidelity, full-task simulation.

With imagination, an instructional designer may see recognition-primed decision-making at work in the performance of experts in many domains. An expert teacher appears to recognize when to give students free reign and when to rein them in. An expert social services professional recognizes the signs of bi-polar disorder early in a client interview and redirects a manic cycle. An expert sales representative recognizes the opportunities embedded in a customer's objections and closes the order. A port security officer recognizes a packing crate that ''doesn't look right'' and takes a closer look. In all of these scenarios, trained competence has combined with experience to create expertise. However, while expertise occurs naturally over time for many learners and practitioners without systematic instructional interventions, there are opportunities, such as recognition training, to hasten the progression of advanced learners to expert status...to get more people over the bar faster.

Traditionally, the culture of instructional design is that we aren't responsible for the development of expertise. Expertise is seen as the realm of individual coaching, mentorship, and massed experience while the systematic design of instruction has focused—very successfully—on the codification and transmission of declarative knowledge and procedural skills. Maturing theories of expertise and expert performance, however, suggest and support a greater role for instructional design in the systematic development of expertise.

Accepting the value and feasibility of the recognition training approach described in this article still leaves many challenges and issues to be addressed: What types of skills might be amenable to recognition training? Who are the experts and how can we identify them? How can the mechanisms of experts' recognition skills be revealed? When might learners gain most from recognition training? Can premature recognition training hurt the schema development of learners? How can performance gains be observed and measured? These questions will be addressed primarily through the development and reporting of recognition training programs in a variety of domains—many of which were represented in this article with hypothetical examples (apologies to readers who have real expertise in these areas).

The recognition training approach that has been described in this article is based on the critical assumption that training skilled but less-than-expert learners to produce recognition behavior equivalent to what experts display will create, or at least hasten, expertise. A modest amount of research, primarily in training perceptual-cognitive sports skills, supports this assumption. However, more training-based research is needed, in more and different domains of expertise. Ironically, as much as expertise research is ripe for the instructional design picking, the research also needs to be applied in order to become more fruitful.

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