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Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions

DAVID P. BROADBENT[1], JOE CAUSER[1], A. MARK WILLIAMS[2] & PAUL R. FORD[1]

[1]*School of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK,*

[2]*Centre for Sports Medicine and Human Performance, Brunel University, Uxbridge, UK*

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Correspondence: D. P. Broadbent, School of Exercise and Sport Science, Liverpool John Moores University, Liverpool, Merseyside, L3 3AF. E-mail: d.p.broadbent@2008.ljmu.ac.uk

Abstract

Perceptual-cognitive skills training provides a potentially valuable method for training athletes on key skills, such as anticipation and decision making. It can be used when athletes are unable to physically train or are unable to experience repeated key situations from their sport. In this article, we review research on perceptual-cognitive skills training and describe future research areas focusing on a number of key theories and principles. The main aim of any training intervention should be the efficacy of retention and transfer of learning from training to field situations, which should be the key consideration when designing the representative tasks used in perceptual-cognitive skills training. We review principles that seek to create practice tasks that replicate those found in the field, so as to increase the amount of transfer that occurs. These principles are perception-action coupling, the contextual interference effect and contextual information, which suggest there should be a high level of similarity between training and real-life performance when designing perceptual-cognitive skills training. In the final section, we discuss the transfer of retained skill acquisition from perceptual-cognitive skills training to field performance, which we suggest to be the key area for future research in this area.

Keywords: Expert performance; skill acquisition; anticipation; decision making

Introduction

Expert performance in sport involves a combination of both motor and perceptual-cognitive skills (Williams & Ericsson, 2005). Perceptual-cognitive skill refers to the ability of an individual to locate, identify and process environmental information so as to integrate it with existing knowledge and current motor capabilities in order to select and execute appropriate actions (Marteniuk, 1976). Perceptual-cognitive skills underpinning performance include, among others, a more efficient and effective use of vision to scan the environment in order to extract relevant information (Williams, Ward, Smeeton, & Allen, 2004). Additionally, expert performers have the ability to recognise sport-specific patterns of play as they emerge (North, Williams, Hodges, Ward, & Ericsson, 2009) and to pick up the early or advance cues emanating from opponents postural movements (Jones & Miles, 1978; Williams & Burwitz, 1993; Williams, Ward, Knowles, & Smeeton, 2002). Moreover, experts are able to generate accurate options of likely outcomes in any given situation based on the refined use of situational probabilities (McRobert, Ward, Eccles, & Williams, 2011). These skills are likely due to the experts having more refined domain specific knowledge and memory structures (Williams & Ward, 2007).

These perceptual-cognitive skills combine to produce two judgments, namely, *anticipation* and *decision making* (Williams et al., 2004), which are the focus of this review. Anticipation is the ability to recognise the outcome of other athlete's actions prior to those actions being executed. Decision making is the ability to plan, select and execute an action based on the current situation and the knowledge possessed (Williams & Ford, 2013). The majority of researchers have examined anticipation processes, with less research being conducted on decision making or how experts acquire the skills underpinning these judgments. Researchers have demonstrated that perceptual-cognitive skills can be trained in sports, including soccer (e.g., Savelsbergh, Van Gastel, & Van Kampen, 2010), badminton

(e.g., Hagemann, Strauss, & Cañal-Bruland, 2006), and tennis (e.g., Smeeton et al., 2005; Williams et al., 2002). Review papers spanning the last 15 years have highlighted key future research areas for individuals examining perceptual-cognitive skill and its training (for reviews, see Causer, Janelle, Vickers, & Williams, 2012; Williams & Grant, 1999; Williams & Ward, 2007; Vine, Moore, & Wilson, 2014).

In this paper, we review perceptual-cognitive skills training involving off-field techniques or *representative tasks*, such as video-based simulations, and we begin the paper with a review of these tasks. Attempts have been made using these tasks to train anticipation (Williams et al., 2002) and decision making judgments (Raab, 2003), as well as skills, such as pattern recognition (North et al., 2009), visual search (Roca, Ford, McRobert, & Williams, 2011) and quiet eye (Causer, Holmes, & Williams, 2011). Perceptual-cognitive skills training has utilised various instructional approaches (Farrow & Abernethy, 2002), manipulations of focus of attention (Hagemann, Strauss, & Cañal-Bruland, 2006), and transfer to fatigue- (Casanova et al., 2013) and anxiety-inducing conditions (Smeeton, Williams, Hodges, & Ward, 2005). To cover all of these topics in detail is beyond the scope of this review, with most of them having been covered well elsewhere in the literature. Therefore, in later sections we concentrate on three areas for future research that may advance the use of perceptual-cognitive skill training beyond its current limits, namely perception-action coupling, structure of practice, and contextual information. These concepts seek to create training conditions that are homogenous to those experienced when physically playing the sport, so as to increase the transfer of learning from training to competition performance. In the final section, we review the transfer of retained skill acquisition from perceptual-cognitive skills training to field performance, which we consider to be the key area for future research in this area.

Representative tasks

The majority of researchers use representative tasks, such as video-based simulations, to train perceptual-cognitive skills (see Figure 1). Representative tasks recreate key situations normally encountered in the performance environment, so that experts are able to reproduce their superior performance under standardized and repeatable conditions (Ericsson, 2003; Pinder, Davids, Renshaw, & Araujo, 2011a). A representative task should allow individuals to search the environment for reliable information, integrate this information with existing knowledge, and complete an appropriate action. To achieve this, life-sized video is often used of key situations from sport that are filmed from the perspective of an athlete. These tasks enable athletes to experience repetition of key situations from their sport in a shorter space of time than they would normally experience when actually playing. They have been used in training to highlight the links between important environmental or opponent cues and outcomes (e.g., Williams & Burwitz, 1993), with the majority of researchers using these methods to train anticipation, as opposed to decision making.

Representative tasks examining perceptual-cognitive skills have often been paired with the temporal occlusion paradigm. Temporal occlusion involves editing video images in order to occlude vision at different time points around key events within the actions of an opposing player (Farrow, Abernethy, & Jackson, 2005). In their seminal study, Jones and Miles (1978) had professional and novice tennis coaches face tennis strokes and predict where the ball would land from footage occluded at various time points. The professional coaches were able to pick-up early information emanating from opponent movements, which led to significantly more accurate predictions in the two earlier occlusion conditions compared to the novices. Whilst the temporal occlusion paradigm demonstrates the expert advantage in anticipation, it does not show the sources of information used when making these judgments.

Researchers have used the spatial occlusion paradigm to reveal the sources of information used by experts during anticipation. Spatial occlusion involves editing video to remove particular areas or information sources from the opponent, such as an arm. It enables researchers to infer which body region provides information that cannot be picked up elsewhere, through decrements in anticipation occurring when that body region is occluded (Williams & Davids, 1998). However, this does not necessarily mean that the body region or cue in isolation is critical. It may be the removal of the cue that distorts or removes the relative motion between regions of the body. Alternatively, it may be that removal of a critical cue does not impact on performance, as expert performers are able to extract information from several different sources.

The temporal and spatial occlusion methodologies have been used to train anticipation and decision making in athletes. Williams and Burwitz (1993) used the temporal occlusion paradigm to examine the anticipation of soccer penalty kicks by expert and novice goalkeepers. The expert group were significantly more accurate at saving penalties under the two conditions that occluded prior to foot-ball contact, when compared to the novice group. Based on the accuracy scores and responses to a questionnaire about the kinematic cues used, the researchers developed a penalty saving strategy and training program. For example, in order to predict shot height, individuals were directed towards the trunk position prior to foot-ball contact, and then to the initial portion of ball flight (Williams & Burwitz, 1993). The training program involved video-based coaching to improve the anticipation judgments of the novices. The training group significantly improved their response accuracy compared to a control group. Subsequently, other researchers have successfully improved anticipation using occlusion techniques alongside various instructional methods during training (e.g. Smeeton et al., 2005).

Much of the research conducted on perceptual-cognitive skill is in line with one or more of the stages in the *Expert Performance Approach* (Ericsson & Smith, 1991). The approach is a three-stage model for the empirical analysis of expertise. In the first stage, naturally occurring domain-specific tasks that capture superior performance are presented in a standardized and realistic form using representative and reproducible experimental tasks (Ericsson & Ward, 2007). The second stage is to use the representative tasks to identify the mediating mechanisms underlying the superior performance by recording process-tracing measures, such as eye movement recording, verbal protocol analysis, and/or representative task manipulations (Williams & Ericsson, 2005). Finally, the third stage should examine how the mediating mechanisms are acquired and the effects of different practice activities on their acquisition (Ericsson, 2003). The approach provides a framework for future research in the area of perceptual-cognitive skill.

Perception-action coupling

Some researchers have raised concerns over the use of representative tasks for training, particularly in regards to the ecological validity of this approach, or how closely the actions in the training environment replicate those in the performance environment (Pinder et al., 2011a; Van der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). Early methods were criticized for using simplistic responses to small and static visual displays, all of which were thought to limit the expert advantage (Williams & Grant, 1999). The size of the visual display may be more important for research on certain perceptual-cognitive skills, such as the use of postural cues, compared to some other skills, such as recognition judgments where experts perceive relative motion within the display (Williams, North, & Hope, 2012). Many researchers now use large screens that allow life-size images to be projected and show dynamic rather than static images. However, some studies in this area are still criticised for the use of simplistic responses, such as button pressing and written or verbal responses (e.g.

Savelsbergh, van der Kamp, Williams, & Ward, 2005). Two critical components proposed in the design of training environments are *functionality* of the task and *action fidelity* (Pinder et al., 2011a). Functionality refers to whether the constraints a performer is exposed to, and must act upon in the task, match those that they will be exposed to in the performance environment. Similarly, action fidelity requires that the performer is allowed to complete a response that is the same as that produced in the performance environment. Central to these ideas is the reciprocal relationship between perceptual and motor processes and the complementary contributions of the ventral and dorsal cortical visual systems to performance (Milner & Goodale, 2008; Van der Kamp et al., 2008). There is evidence to suggest that the maintenance of both functionality and action fidelity in practice is critical to accurately capture the action of interest (Pinder, Davids, Renshaw, & Araujo, 2011b).

Differences between laboratory studies and the real-world have been shown for some of the perceptual-cognitive processes underpinning expert performance (Farrow & Abernethy, 2003; Mann, Abernethy, & Farrow, 2010; Mann, Williams, Ward, & Janelle, 2007; Van der Kamp et al., 2008). A recent meta-analysis has shown that the advantages of expert over novice participants in perceptual-cognitive skills studies are directly proportional to how close the action completed in a simulated environment is to the actual action required in sport (Travassos, Araujo, Davids, O'Hara, Leito, & Cortinhas, 2013). The majority of the studies investigating perception-action coupling have concentrated on the use of postural cues for anticipation of an action (for an exception, see Paterson, van der Kamp, Bressan, & Savelsbergh, 2013). Dicks, Button, and Davids (2010) investigated visual search and response behaviours of soccer goalkeepers facing penalty kicks. The goalkeepers faced kicks in five experimental conditions that had all been previously used in perceptual-cognitive skills studies. The experimental protocols included two video conditions in which the keepers either produced a verbal response or a simulated joystick movement. They also included three

in situ conditions in which the keepers either produced a verbal response, a simplified body movement, or an actual interceptive movement response or "save" as they would during match-play. The study did not include a complex movement condition in the video conditions (e.g. Pinder et al., 2011b). Participants were more accurate in the *in situ* conditions compared to the video simulation conditions. In the conditions with limited movements for participants, the keepers spent more time fixating on the movements of the penalty kick taker (head and feet), rather than the ball. In comparison, when goalkeepers were required to attempt an actual penalty save *in situ* they fixated earlier and for a longer duration on the ball when compared to the movements of the taker and to the other conditions. However, the number of possible shot locations was lower (n = 2) in the "save" condition compared to all other conditions (n = 6) and the video condition showed less ball flight than *in-situ*, which may have led to the observed differences in visual search between conditions. Overall, findings suggest that laboratory tasks may fail to adequately recreate the environmental characteristics of many real-world settings (Dicks et al., 2010).

However, some researchers have found no difference between coupled and uncoupled responses in perceptual-cognitive skill studies (Ranganathan & Carlton, 2007, Williams et al. 2004). Williams et al. (2004) examined the effect of perception-action coupling during *training* of anticipation skill. Participants practiced anticipating tennis serves in an on-court scenario, either responding verbally during practice, or physically returning the serves, whereas a third control group just received technical training. There were no significant differences between the three groups in the pre-test, but in the post-test both the perception-action and perception only training groups recorded faster anticipation compared to the technical training group, with no difference found between the two perception groups. Further research is required to assess perception-action coupling and also to examine whether

these findings extend to other perceptual-cognitive skills, such as pattern recognition and situational probabilities.

High levels of task functionality and action fidelity seem to be required for researchers examining the processes and mechanisms that underpin expert performance in sport. However, a suitable balance is required between the need to maintain ecological validity on the one hand and the desire for internal validity and experimental control on the other (Causer, Barach, & Williams, 2014). A related question for future research is whether perceptual-cognitive skill training that *does not* involve a movement response can lead to improved physical performance during competition. One advantage of perceptual-cognitive skills training is that athletes can engage in it when they are not able to physically practice; such as when injured, travelling to competition, resting at home, or recovering from training (Williams & Ford, 2013). In cases where athletes are unable to physically respond, then perceptual-cognitive skills training without a movement response may be superior to other activities, acting as a form of observational learning (Horn, Williams, & Scott, 2002), albeit with greater cognitive effort (Lee, Swinnen, & Serrien, 1994). Well-designed physical practice is likely superior in maintaining the coupling between perception, cognition and action when compared to perceptual-cognitive skills training and should take priority when athletes are able to engage. The main test of any practice activity in sport is how well the aspects of performance being practiced transfer to retained improved performance in the competition format of the sport (Rosalie & Mueller, 2012). In the following sections, we review research and make recommendations on the structure of practice and transfer of learning from perceptual-cognitive skills training to the field.

Structure of practice

There is little doubt that extensive practice and training is necessary to reach the very highest levels of performance in sport (Ericsson, 2003). Researchers have demonstrated that

the manner in which practice is organized influences the performance and learning of skills. A robust finding in the motor learning literature is the *contextual interference* (CI) effect (Magill & Hall, 1990). Practice schedules involving high CI (i.e., random schedule) result in poorer performance during acquisition, but promote superior long-term learning and transfer of the skills, when compared to low CI conditions (i.e., blocked schedule; Lee, 2012). The CI effect has been extensively examined in a variety of motor learning tasks (for reviews, see Lee, 2012; Magill & Hall, 1990).

To date, there is limited research examining whether the CI effect extends to perceptual-cognitive skill training in sport. Memmert, Hagemann, Althoetmar, Geppert, and Seiler (2009) investigated the CI effect in the acquisition of anticipation by novice badminton athletes. Participants practiced under either two blocked conditions (lateral before depth or depth before lateral dimension), or a random schedule. The protocol involved viewing temporally occluded overhead badminton shots from the perspective of the returning player that were shown in the upper left-hand corner of a computer screen. On the right-hand side of the screen was an image of a badminton court that participants had to click on to report where they predicted the shuttlecock would land. All participants completed a pre-test, 6 training sessions where feedback was provided after each trial, a mid-test, a post-test, and a 7-day retention test. There were no between-group differences in the accuracy of anticipatory judgments across acquisition and retention. The lack of differences is most likely due to participants only practicing anticipatory judgments of one skill, the badminton overhead stroke to different landing locations. By definition, CI is the scheduling of practice for a number of different skills, not a single skill.

In comparison, Broadbent et al. (under review) required intermediate tennis players to anticipate the direction of three distinct tennis shots (groundstroke; volley; smash shot) shown on life-size video filmed from a first person perspective and occluded around ball-

racket contact. Response accuracy scores were recorded in a pre-test, during acquisition, on a 7-day retention test and in an on-court test used to measure transfer of learning. Participants responded by executing the movement of a return shot and verbalising the anticipated shot location. During the acquisition phase, one group had a blocked schedule of practice in which the three types of tennis shots were practiced in separate blocks. The other group had a random schedule of practice in which the three shot types were practiced in a quasi-random order. Findings showed some support for the previous literature and the CI effect. There were no between-group differences in response accuracy across the acquisition phase, which contradicts the 'typical' CI effect. However, the random practice group reported significantly higher response accuracy in the 7-day laboratory-based retention tests compared to the blocked group (Figure 2). Moreover, in the 7-day transfer test to an on-court protocol the random group significantly reduced their decision time compared to the blocked group (Figure 3). Findings provide the first indication that the CI effect extends beyond the motor learning literature into the perceptual-cognitive skills literature.

From an applied perspective, practitioners engaging athletes in simulation training to improve perceptual-cognitive skills should look to promote high CI in order to incur long-term learning and transfer of the skills. From a theoretical perspective, future research should investigate whether the explanations for the CI effect from the motor skills literature can be applied to this new domain. Two main theories have been forwarded to explain the CI effect (Lee, 2012). First, the elaboration hypothesis holds that random practice promotes more comparative analysis between the multiple skills being practiced, whereas the repetitive nature of blocked practice promotes less analysis (Schmidt & Lee, 2011). Second, the reconstruction hypothesis postulates that random practice promotes short-term forgetting due to the interference between tasks, causing participants to reconstruct an action plan in order to execute each new attempt at the task. In contrast, during blocked practice only one action

plan is used across the multiple attempts at the same task (Schmidt & Lee, 2011). Further research is required to reveal the underlying cognitive mechanisms that lead to the CI effect.

There are other aspects of practice structure that have not been addressed fully in perceptual-cognitive skills training. When performing in sport competition, an athlete's perceptual-cognitive skills are constrained not only by their level of expertise in the sport and the current situation in the performance, but also by the contextual information within the situation (McRobert et al., 2011). Contextual variables include the score of the game; the time in the game; the athlete's characteristics, tactics, and tendencies; opponent characteristics, tactics and tendencies; pitch surface; and the weather, as well as in some sports the characteristics and tendencies of teammates (McPherson & Kernodle, 2003). Contextual variables are rarely examined in perceptual-cognitive skill training in sport despite their potential importance. An exception in the perceptual-cognitive skills literature is McRobert et al. (2011; see also Paull & Glencross, 1997) who investigated context-specific information and its effect on anticipation performance in cricket. Skilled and less-skilled batters faced life-size video of deliveries from bowlers that were occluded after 80 ms of ball flight. In a low-context condition, participants responded to 24 balls from six bowlers presented in a random order. In the high-context condition, participants responded to four fast bowlers who each delivered six balls in one block. The high-context condition replicated an actual match condition known as an "over" in cricket. It exposed participants to contextual variables linked to their opponent's characteristics, tactics and tendencies. The high-context condition led to higher response accuracy scores for both groups when compared to the low-context condition. Moreover, visual search data revealed that fixation duration was shorter in the high- compared to the low-context condition, suggesting that the additional pre-performance information allowed the skilled batters to extract the information from the display more efficiently. Contextual information may act as an informational constraint on

performance (Vicente & Wang, 1998), increasing the functionality of the task. Further research is required to examine the effect on skill acquisition of real-world contextual variables in perceptual-cognitive skills training.

Retention and transfer of learning from practice

The key consideration when designing any practice activity is the retention and transfer of learning from that activity to the complexity of field performance. Retention is a measure of learning and refers to the persistence or lack of persistence of the performance once a period of time has passed after the practice trials ended. There is extensive research on the long-term retention of various motor skills (Schmidt & Lee, 2011). Neumann and Ammons (1957) provide a classic example where they assessed learning of a discrete motor skill at retention intervals of one min, 20 min, two days, seven weeks, and one year. They showed that decrements in performance became progressively greater as the length of the retention interval increased. Researchers examining perceptual-cognitive skills training have started to include retention conditions as opposed to just a post-test. Some researchers have shown that perceptual-cognitive skills training has led to improved anticipation and decision making that has been retained after periods of 14 days (Gorman & Farrow, 2009), four weeks (Gabbet, Rubinoff, Thorburn, & Farrow, 2007; Raab, 2003) and five months (Abernethy, Schorer, Jackson, & Hagemann, 2012).

However, much of the previous research on perceptual-cognitive skills training does not assess whether improvements during acquisition actually transfer to field situations (Rosalie & Mueller, 2012). In the previously mentioned studies, only the paper by Gabbet et al. (2007) demonstrated significant improvements to an actual match situation following a retention period. Other researchers either failed to include a transfer test (Raab, 2003), administered a laboratory-based transfer test to a stressful condition (e.g., Abernethy et al., 2012), or found no significant improvement to performance in actual competition (Gorman &

Farrow, 2009). A few researchers *have* assessed the transfer of perceptual-cognitive skills from laboratory-based training to the field (Farrow & Abernethy, 2002; Smeeton et al., 2005; Williams et al., 2002). While these studies have shown successful transfer, the field-based protocol is administered as part of a pre- and post-test occurring close to the practice phase and so not assessing the retention of these transferrable skills.

Researchers investigating the benefits of quiet eye (QE) skills training have demonstrated retained transfer of learning to real competition (Causer et al., 2011; Vine, Moore, & Wilson, 2011). The QE period is defined as the final fixation on a specific location or object for a minimum of 100 ms (Vickers, 1996). The onset of QE occurs before the final movement of the task where the performer is thought to set the final parameters of the movement to be executed (Causer et al., 2011). Longer QE periods are associated with greater expertise and success when compared to shorter QE periods, and this ability can be trained (for a review, see Vine et al., 2014). Vine et al. (2011) randomly assigned a group of elite golfers to either a QE training or control group. Participants recorded their putting statistics over 10 rounds of competitive golf (maximum of 3 months) before and after the training interventions. The training for both groups consisted of video feedback of their gaze behaviour while they completed putts, with the QE-trained group receiving additional instructions related to maintaining a longer QE period. Pre-test performance was not different between groups, but post-intervention the QE-trained group holed more putts and left the ball closer to the hole more frequently compared to the control group, and these advantages transferred to real competition. The successful transfer of QE training to real-world performance may be due to the high fidelity of the actions executed during training. Alternatively, QE may be a simpler skill to acquire and transfer to competition compared to other perceptual-cognitive skills, such as decision making. However, it is beyond the scope of

the current paper to review issues surrounding QE training as these have been discussed at length elsewhere in the literature (for a review, see Vine et al., 2014).

In relation to anticipation training studies, generally researchers have found high scores and no between-group differences for response accuracy in the field-based post-test compared to the pre-test (Smeeton et al., 2005; Williams et al., 2002). The high scores and lack of improvement in response accuracy in the field-based tests could be as a function of the speed-accuracy trade-off inherent in these tasks. Moreover, many anticipation-training studies contain responses that are low in fidelity, which may further affect the transfer of learning. Alternatively, it may highlight the difficulty of creating challenging enough conditions for participants in the field. In the field, participants can usually wait to respond until the ball is in flight, whereas in the laboratory the occlusion paradigm forces them to make decisions before the ball is in flight. Therefore, researchers investigating anticipation should seek to use sports tasks that actually require anticipatory responses in the field, such as a tennis volley, as opposed to those that require it less so, such as deep ground stroke in tennis (Triolet, Benguigui, Le Runigo, & Williams, 2013). Furthermore, the temporal occlusion paradigm can be recreated *in situ* by using liquid crystal goggles that are capable of quick transitions between transparency and opacity (Milgram, 1987). Researchers examining perceptual-cognitive skills *in situ* using liquid crystal goggles have usually reproduced the expert advantage that has been found in laboratory studies using video simulation (Farrow et al., 2005; Mann, Abernethy, Farrow, Davis, & Spratford, 2010). In the future, researchers should seek to use field-based transfer protocols as the norm to investigate whether skills acquired during perceptual-cognitive skills training actually transfer to improved complex performance in the field. Those transfer conditions should also look to recreate arousal states that occur in competition, such as high-anxiety (e.g., Alder, Ford, Causer & Williams, under review) or fatigue (e.g., Casanova et al., 2013), so as to increase the fidelity of the test.

Conclusion

Perceptual-cognitive skill training provides an ideal method for developing anticipation and decision making judgments in athletes. Although researchers have made much progress in examining this area, further research is required to resolve the key question from this review as to whether perceptual-cognitive skills training provokes transfer of learning to improved and retained performance in the field. A number of the principles outlined in this review suggest that the representative tasks used in perceptual-cognitive skills training should replicate as closely as possible the real-world to improve the transfer of learning. These principles include the structure of practice, perception-action coupling, and contextual information, which we believe should be the focus of future research towards answering the main question on transfer. Future research should seek to include field-based transfer tests as the norm and where possible long-term transfer tests to gain a true understanding of the benefits of perceptual-cognitive skills training.

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Figures

Figure 1. Example set up of a laboratory video simulation technique for the acquisition of anticipation skills in tennis from Broadbent et al. (under review).

Figure 2. Mean (SE) response accuracy (%) for the blocked and random groups in a video simulation tennis anticipation task in the pre-test, 3 training sessions, 7-day, and 2-month retention test. *p < .05. Adapted from Broadbent et al. (under review).

Figure 3 Mean (and standard deviation) response accuracy percentage (RA; %) and decision time (DT; ms) in the field pre-test and 7-day transfer tests for the blocked and random group.*p < .05. Adapted from Broadbent et al. (under review)

Figure 4.Mean (SD) response accuracy (%) for experienced and inexperienced soccer goalkeepers in a penalty anticipation task across four occlusion conditions; 120 ms before foot-ball contact, 40 ms before contact, at contact (0 ms), and 40 ms after foot-ball contact. *p < .05. Adapted from Williams & Burwitz (1993)