IMPROVING ANTICIPATION AND DECISION MAKING IN SPORT

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Summary
Traditionally, athletes and others involved with sporting organizations have tended to overlook psychological aspects of performance such as anticipation and decision making in favour of improving physical attributes and/or technical ability. However, as individuals proceed to the upper echelons of sport, differences in physical and physiological characteristics appear less likely to discriminate, while the importance of other components, such as the ability to anticipate and make decisions, is magnified. The nature of sport means high levels of uncertainty, requiring athletes to anticipate action requirements before selecting the most appropriate response from a range of possibilities. In this chapter, we outline key perceptual-cognitive skills involved in sport. We highlight how these perceptual-cognitive skills may be measured and enhanced through specific training interventions.

Introduction
In sport, athletes confronted with complex and rapidly changing environments are often required to make critical decisions in high-pressure, temporally constrained scenarios (Williams, 2000). Inherent limitations in reaction time and movement time necessitates that successful athletes must anticipate or predict future events based on limited preparatory information (Hagemann et al., 2006). In order to deal effectively with such constraints, athletes rely on a range of perceptual-cognitive skills. These skills include the ability to recognize advance (i.e. early arising) visual information cues, identify patterns/structure in play and an awareness of likely event probabilities (Causer et al., 2012).

Expert athletes can reduce the amount of information processed to create a coherent perceptual representation by selectively attending to more pertinent cues (Williams et al., 2009). Furthermore, task-specific knowledge built up through experience is thought to help expert players attend to these more pertinent areas of the display, making it easier to surmise situational probabilities from events previously experienced, allowing for more effective processing of contextual information (Williams, 2009). This ability, which in lay terms is often referred
to as ‘game intelligence’, is thought to develop through experience from the accumulation of hours spent in deliberate practice (Ericsson et al., 1993). However, researchers have also highlighted the potential effectiveness of systematic training programmes in facilitating the more rapid acquisition of these skills (Causer et al., 2011; Smeeton et al., 2005).

In this chapter, we outline key perceptual-cognitive skills that underpin superior anticipation and decision making in sport. We provide an overview of the equipment and methods used to capture and analyse performance in both laboratory and field settings. Practical implications for performance analysts and sports performance are discussed. In finishing, we outline how data captured using these methods may be used to design training interventions that can improve performance in various sporting contexts.

### Anticipation and decision making in sport

In many domains, researchers have argued that the ability to make decisions and anticipate future demands are the most important factors underlying expertise, particularly in situations with limited time to respond and/or when life is at threat (Causer and Williams, 2012). In diverse fields such as military combat (Ward et al., 2008), law enforcement (Vickers and Lewinski, 2011), medicine (Joseph and Patel, 1990) and sport (Williams and Abernethy, 2012), scientists have attempted to identify how these skills differentiate experts from their less-expert counterparts. Several distinct differences in perceptual-cognitive expertise are evident across skill levels (Williams, 2009).

Ericsson and Kintsch (1995) suggested that experts acquire sophisticated complex skills for storing information in long-term memory in accessible form that enable the processing limits on working memory to be either bypassed or changed (increased). These skills promote rapid long-term memory encoding and enable selective access to this information when required, hence expanding the available capacity of short-term memory for information processing (Ericsson and Lehmann, 1996). With extensive practice, experts index information in such a way that they can successfully anticipate future retrieval demands. It is furthermore suggested that retrieval cues in short-term working memory facilitate immediate and efficient access to information stored in long-term memory (Ericsson and Kintsch, 1995). This expansion of working memory provides the expert performer with greater capacity to engage in planning, reasoning, evaluation and other key activities needed for elite performance (Ericsson and Delaney, 1999). A brief overview of the key perceptual-cognitive skills that underpin superior anticipation and decision making is provided below.

### Identifying familiarity in sporting action

It appears that experts are better than novices at recognizing and recalling structure in evolving sequences of sports action. Methods borrowed from cognitive psychology, such as recognition and recall paradigms, have been used to illustrate that experts exhibit superior domain-specific memory compared to non-experts (de Groot, 1964; Simon and Chase, 1973). In sport, North et al. (2011) recruited expert and less-expert soccer players to view dynamic film stimuli and anticipate event outcomes. Previously viewed and novel sequences were presented in film or point-light display format with players represented as points on a background display. Participants were required to indicate if they recognized the film clip (i.e. shown previously). Experts demonstrated superior anticipation accuracy and better discrimination between previously seen and novel stimuli. These findings suggest that experts developed more complex memory structures, which enabled them to predict event outcomes more effectively than their less-expert counterparts.
counterparts. The authors argued that experts pick up relational information between players in order to make effective recognition judgments, whereas less-expert players rely on structural or superficial information. Preliminary findings suggest that the ability to recall and recognize patterns of play transfer across similar sports (e.g. netball to basketball) (Abernethy et al., 2005; Smeeton et al., 2005).

Knowledge of situational probabilities

It has been reported that expert performers are able to make use of expectations or situational probabilities to facilitate anticipation in sport. The experienced performer can use his/her superior knowledge base to dismiss highly improbable events and allocate attention to more likely occurring events (Gottsdanker and Kent, 1978). Alain and colleagues (Alain and Proteau, 1980; Alain and Sarrazin, 1990; Alain et al., 1986) showed that expert racket players could accurately predict the outcome of rallies before they ended. Players evaluated the probability of each possible event that could occur in any given context and then used this information to maximize the prediction of subsequent behaviours and outcomes. Similarly, Ward and Williams (2003) reported that elite soccer players were superior to novice counterparts at identifying players who were in a better position to receive the ball and applied a more refined probability hierarchy to decrease the decision threshold necessary to predict successfully. Expert players were better at determining the importance of each option presented, effectively priming the search for new information and ensuring that the most pertinent contextual information was extracted.

The effect of contextual information has been investigated in other sports, such as cricket (McRobert et al., 2011) and tennis (Crognier and Féry, 2005). Crognier and Féry (2005) employed three different subjective context-related manipulations to examine effects of visual information on anticipating outcomes when playing tennis against an opponent. They reported more accurate final ball location predictions during the high-initiative (high-context) condition in which a participant viewed the preceding shots by the opponent, as compared against the moderate-initiative and weak-initiative conditions. The high-initiative condition allowed the participant to control the rallies so that their opponent was on the defensive prior to the end of the rally. This condition also contained subjective context information on the strengths and weaknesses of the opponent and their relative position on court in relation to the participant. In comparison, the moderate-initiative and low-initiative conditions required either the participant or the opponent to set the ball; therefore, it contained no rallies and thus no subjective context information before vision was occluded and the participant was asked to anticipate the location of the opponent’s final shot.

McRobert et al. (2011) reported similar findings in cricket, with expert batters showing greater prediction accuracy, more effective search behaviours and enhanced verbal reports on thinking. Moreover, when the opponent was viewed multiple times (high context), mean fixation time was reduced. Also, all batters demonstrated improved performance and different thought processes in the high-context condition compared to low context when they responded to the opponent without having seen them bowl previously. The above studies demonstrate how context-specific information influences performance in dynamic sporting tasks.

Picking up advance information (advance cue utilization)

Advance cue utilization refers to picking up information early in an action sequence (Abernethy, 1987). Jones and Miles (1978) examined whether tennis players could anticipate successfully the direction of serves based on advance information. Film clips were occluded 42 ms
before and 126 ms and 336 ms after ball–racket contact. Expert players were better than novices at predicting direction of serve in the −42 ms and 126 ms occlusion conditions, whereas no differences in scores were evident in the 336 ms condition. These results suggest that expert tennis players were superior to less skill players in the use of advance information to predict serve direction. Similar work has been conducted in other sports using both temporal (e.g. selectively editing a film into time phases where progressively more of a movement is presented) (Abernethy, 1990; Abernethy and Russell, 1987; Farrow et al., 2005; Salmela and Fiorito, 1979; Williams and Burwitz, 1993) and spatial (e.g. masking/occluding important areas/cues in the visual field) (Abernethy and Russell, 1987; Causer and Williams, under review; Williams and Davids, 1998) occlusion paradigms.

The visual system

Scientists have recorded eye movements to investigate the gaze characteristics used in sport (Janelle et al., 2000). (See Figure 2.1 for example of an eye-movement recording.) A particular focus has been on identifying how visual search characteristics differentiate expert and novice performers. Mann et al. (2007) conducted a meta-analysis of nearly three decades of empirical work in this area. Although the strategies employed are task-specific, experts often exhibit fewer fixations of longer duration than non-expert comparison groups. While not a direct measure of attention per se, the longer the eye remains fixated on a given target the more information is thought to be extracted from fixated cues in the display. Fixation location is assumed to reflect the important cues used in decision making, whereas fixation duration (search rate) is thought to reflect the information-processing demands placed on the performer. Experts have been reported to use ‘visual pivots’ or ‘anchor points’ (Ripoll et al., 1995; Williams and Davids, 1998; Williams and Elliott, 1999) to reduce the amount of eye movements required, thus reducing the demands on information processing and improving processing efficiency.

Figure 2.1 An illustration of eye movement data being gathered in the sport of curling. The image in the top left-hand corner presents the curler at the moment of releasing the stone, whereas the image underneath presents the performer’s pupil and corneal reflection. The image on the right is picked up by the head-mounted scene camera, with the cross-hairs representing the curler’s point-of-gaze
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In summary, thus far we have identified some of the key perceptual-cognitive skills that underpin superior anticipation and decision making in various sporting environments. Specifically, we have identified how experts can have a significant advantage over less-experts in many situations by picking up advance visual information cues, using knowledge of likely event tendencies, and identifying familiarity with evolving action sequences. In the next section, we identify key skills and attributes that can be used to develop systematic training programmes to enhance anticipation and decision making in athletes.

Identifying information using advanced statistical techniques

Principle component analysis (PCA) is a common statistical technique used in biomechanics analyses for finding patterns in data. In brief, PCA is used to reduce large numbers of variables to smaller numbers of components that account for the majority of variance (for a review, see Daffertshofer et al., 2004). Performance analysts too may have access to large databases involving, for example, kinematic joint data of individual players for movement technique analysis (e.g. from motion-capture systems, such as Vicon or Qualysis systems). The same holds for movement analysis of single and/or multiple players (e.g. from motion-tracking systems, such as Prozone or Amisco). As noted, PCA may be used to identify key components that account for the majority of variance in data. Ultimately, this approach could highlight key areas for attention during training, for instance, as well as in scouting future opponents.

Cross correlations can also be used to identify patterns, consistencies and relationships between variables. Cross-correlations are based on the assumption that linear relationships exist between two sets of kinematic time series data (e.g. joint pairs), but do not assume that these variables change in synchrony during the movement (Mullineaux et al., 2001). By introducing time lags between data sets and calculating the corresponding correlation coefficients, researchers can obtain an indication of the type of relationship between body segments, the degree of linkage between body segments and the stability of coordination patterns when applied to repeated trials (Temprado et al., 1997). For example, cross-correlations could be used to determine the consistency of a tennis player’s serve or a cricket bowler’s release action. Using high-speed video cameras and cross-correlation techniques, small temporal and spatial inconsistencies can be highlighted. Comparison between successful and unsuccessful trials, or training and competition scenarios, can determine the most efficient and/or effective technique for an individual. Coaches can then use this information to ensure this technique is reproduced consistently.

Protocols to measure advance cue utilization

Established video-based protocols can be used to assess anticipation and decision making in sport. These methods would require video footage of a certain skill or series of actions – for example, a series of soccer penalty kicks. Video information could then be edited temporally and/or spatially in order to assess anticipation and decision making – of the soccer goalkeeper given the above example. Information access (visual cues) and time available will influence perceptual strategies and so occlusion techniques can be used to manipulate these constraints (for a review of available procedures, see Carling et al., 2009; Williams and Abernethy, 2012). Temporal occlusion (see Figure 2.2) is used to manipulate the time course of access to cues and has been used frequently to distinguish between skill levels (Jackson et al., 2006). The temporal occlusion paradigm can also be used in situ using liquid crystal goggles that are capable of transitions between transparency and opacity within 5 ms (Milgram, 1987). Liquid crystal goggles
provide an important advance in efforts to replicate the natural environment. The spatial or event occlusion (see Figure 2.2) technique is used to mask certain information in the visual field. A decrease in performance relative to a non-occluded control condition suggests that the occluded area contains key information concerning that particular movement.

Using these techniques, performance analysts can identify critical visual cues, as well as what time in the action sequence this information becomes important. Information derived can subsequently be used to create training programmes to improve attention on specific information in order to enhance anticipation and decision making. Soccer goalkeepers may fixate on a certain part of a penalty taker’s posture that enables good anticipation of direction and flight characteristics of the ball. This technique can also be used to demonstrate how deceptive movements in sport can be anticipated. For example, a player executing a dummy pass in rugby may exhibit certain postural cues that are inconsistent with a ‘normal’ pass. The process involved in identifying these differences may then allow players to practice avoiding negative effects of deceptive movements by opponents.

**Situational probabilities**

The actions of opponents can be coded and a database established to identify trends or preferences for individuals and/or teams. In so doing, both general tactics as well as specific tactics based on, say, the score and/or time in a given game might be developed. By identifying patterns in advance, players and coaches are able to prepare for the most likely events. In cricket, knowledge of previous batting behaviours of opponents in terms of shot selection, target areas, ball end point and so on, for example, may provide the captain of the bowling team an advantage when setting field positions and instructing bowlers. Similarly, tennis
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Serves from an upcoming opponent may be coded to identify if a particular type of serve is preferred at critical game points, so offering the player a possible advantage in anticipating various aspects of the serve (e.g., direction, speed and/or spin). Thus, recording of performance data over time may allow for patterns of play, or tactical idiosyncrasies, to be identified. By comparing successful and unsuccessful events, critical behaviours and other variables prevalent in effective performances might be established. With this knowledge, alterations to key performance variables can be targeted in future events to increase the probability of successful performance.

The results or outcomes of games may be predicted or forecasted using techniques such as time series analysis, regression analysis and artificial neural networks, among others. These techniques have previously been used to predict scores in soccer games (Stefani, 2003) and attendance in baseball games (Siegfried and Eisenberg, 1980), and to investigate the effects of feedback in motor skill acquisition (Blackwell et al., 1991).

In summary, skill acquisition specialists are concerned with understanding how information from the environment might best be used by athletes. The techniques identified in previous sections illustrate what information is available and how athletes might be guided towards attending to and exploiting this information. Performance analysts have the important task of identifying structure in seemingly otherwise random complex environments. Using data from training and games, models of behaviours can be created and performance outcomes forecasted, thus providing coaches with information regarding possible tactics derived from trends in opponent behaviours. Gathering data and modelling performances allows for effective tactics, behaviours and structures to be identified that can assist in developing technique and tactical awareness in players. In collaboration with coaches and skill acquisition specialists, performance analysts can be involved in developing and implementing training programmes that facilitate more rapid acquisition of perceptual-cognitive skills in athletes.

Training anticipation and decision making

Several researchers have examined the potential of training perceptual-cognitive skills in sport (Causer et al., 2012). Williams et al. (1999) suggested that perceptual training programmes should use expert search patterns as models of perceptual performance, and so include tasks that contribute to developing a comparable knowledge base upon which these search strategies are based. Perceptual-cognitive interventions that help develop the knowledge base underlying expert perception have more practical utility in aiding acquisition of expert performance than clinically based visual skills training programmes that focus on improving visual function (Williams and Grant, 1999).

The majority of training studies in sport have utilized video-based simulations including instruction and varying amounts of feedback. These training programmes attempt to highlight links between important display cues and outcome (Ward and Williams, 2003). Williams and Burwitz (1993) applied the temporal occlusion paradigm to a penalty kick in soccer. Novice goalkeepers showed significant improvements in anticipatory performance when the relationship between important postural cues and penalty kick outcome were highlighted. More recently, Savelsbergh et al. (2010) attempted to modify visual search behaviours of inexperienced soccer goalkeepers in order to improve performance. The goalkeepers were required to anticipate penalty kick direction from video clips projected onto a screen and respond by moving a joystick. The perceptual learning group viewed clips that highlighted key information from the run-up sequence, the training group viewed the unedited videos and a control group performed the pre- and post-tests only. The results showed that visual
search behaviours of the perceptual training group changed significantly and improved initiation of the joystick movement. This initiation coincided with the timing of the most important visual information and led to significantly better performance than the training and control groups.

Raab et al. (2005) compared the effectiveness of decision training and/or behavioural practice in elite table tennis players. Twenty table tennis players were assigned to either a behavioural or a decision training group. The behavioural group received technical training at regular intervals emphasizing targeting accuracy in the forehand and backhand strokes. The decision group received the same training as the behavioural group for the first four weeks and in the remaining five weeks were provided with video feedback and modelling oriented towards improving transitions between backhand and forehand. The two groups were assessed on how well they performed strokes technically and on their ability to make the best tactical decisions in competitive game situations. The behavioural group ranked last in tactical decision making and second in technique, while the decision-trained group ranked first in tactical decision making and third in technique. These results show that the combination of technical training and tactical decision making was more successful than technical training alone.

Williams and Grant (1999) provided a detailed review on research in perceptual training. The authors noted the potential of perceptual training programmes but also identified certain shortcomings, not least omission of control and/or placebo groups in several studies. Furthermore, transfer and/or retention tests had not been used adequately in previous research examining whether training facilitated improvements in real-world contexts as well as whether these improvements manifested themselves long term. Williams et al. (2003) addressed these limitations while using a training programme for the penalty flick in field hockey. Laboratory and field-based measures of anticipatory performance were recorded in a training group, a placebo group and a control group. The training group was exposed to video simulation training with key information cues underlying anticipation identified; the placebo group viewed an instructional video focusing on the technical skills involved in hockey goaltending; and the control group completed the anticipation tests only. Participants who underwent the training programme significantly improved performance beyond that of the placebo and control groups in both laboratory and field-based tests. These findings provide strong evidence that cognitive interventions highlighting the most informative cues and corresponding action requirements, whether by video simulation or by instruction in situ, have practical utility in facilitating perceptual skill in sport (Scott et al., 1998; Tayler et al., 1994).

Concluding remarks

In this chapter, we have outlined some of the key perceptual-cognitive skills underpinning anticipation and decision-making in sport. The role of these different perceptual-cognitive skills in performance is well documented in the research literature, but application of this knowledge to develop training programs is not well-established. Although we have reported a number of attempts to develop training simulations under controlled conditions, there remains a paucity of documented case studies involving the use of these training interventions with high-performance athletes. Performance analysts, supported by skill acquisition specialists, have a pivotal role to play in help to bridge the gap between ongoing research work and the translation of new knowledge into applied interventions that may be used at the ‘coal-face’ in high-performance sport.
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References


