PERCEPTUAL-COGNITIVE EXPERTISE AND ITS ACQUISITION IN SOCCER

ANDRÉ ROCA

A thesis submitted in partial fulfilment of the requirements of

Liverpool John Moores University for the degree of

Doctor of Philosophy

This research programme was funded by the Portuguese Foundation for

Science and Technology (FCT) – Ministry of Education and Science

December 2011

Abstract

The aims in the current programme of research were to examine the processes underpinning superior anticipation and decision making in soccer and how these are acquired through practice. The expert performance approach (Ericsson & Smith, 1991) was adopted as a guiding framework. In Chapter 2, an attempt was made to develop and validate a representative task simulation to capture reproducible superior performance in soccer under standardised laboratory conditions. In Chapters 3 and 4, skill-based differences in anticipation and decision making were examined using eye-movement recording and verbal reports of thinking. Skilled soccer players were more accurate at anticipation and decision making compared with less skilled players. When compared with their less skilled counterparts, skilled soccer players revealed more efficient and effective visual search strategies and cognitive thought strategies that varied based on the unique situation and task constraints imposed by the game context. Additionally, in Chapter 4, a continuous and dynamic interaction was identified between the different key perceptual-cognitive skills (i.e., postural cues, pattern recognition, and situational probabilities), with their relative importance varying considerably across game situations. In Chapter 5, the acquisition and development of superior anticipation and decision making in soccer players was examined. Skilled players who were high-performing anticipators/decision makers accumulated significantly more hours per year in soccer-specific deliberate play activities during childhood compared to skilled players who were low-performing and novice players. Findings have implications for theory and practice, extending research in the area of perceptual-cognitive expertise and overcoming some of the limitations with previous research.

List of Contents

List of Tables and Figures

Tables

Figures

Acknowledgements

I have met many people over the last years who have helped to make this work possible. Although I am indebted to all, special notes of thanks are conveyed to the following:

My Director of Studies, Professor Mark Williams for his invaluable expertise, guidance, advice, encouragement, support, and numerous opportunities for which I am exceptionally grateful.

Dr Paul Ford for the priceless role that he has played in this PhD with his guidance, motivation, support, time, high standards, and constructive criticism, particularly during the periods when Mark was at Sydney University.

My Brain and Behaviour research group fellows and other LJMU postgraduates and staff, especially Allistair McRobert, Dr Spencer Hayes, and George Savage, for the precious assistance and great friendship.

To the vast number of players who participated in this research project, giving up their own time with good humour but little reward.

Finally, I would like to dedicate this work to my loved ones, especially to my mum, dad, brother, Geo, and also my friends, who have always supported me.

Heartfelt thanks to you all, I couldn't have done it without you!

Chapter 1

An Expert Performance Approach to the Study of Perceptual-Cognitive Expertise in Soccer

The pursuit of excellence motivates and inspires many individuals across a wide variety of performance domains, such as arts, music, and sports. Only a relatively small number of individuals manage to achieve an expert level of performance, whilst the majority fall by the wayside at various points in the journey. It is this fascination with expertise that has in recent decades led many researchers to examine what sets certain individuals apart from the crowd (e.g., see Ericsson, Charness, Feltovich, & Hoffman, 2006). Thus, researchers have attempted to identify what makes experts excel and what are the mechanisms underpinning superior performance. Such knowledge may provide a principled basis for determining why some people improve at different rates to others or achieve much higher levels of attainment or excellence (Ericsson, 2006). Moreover, this knowledge may be used to evaluate the applicability of prevalent theoretical frameworks of expertise and skill acquisition and help develop interventions for talent identification and development processes across domains (Ericsson & Ward, 2007; Williams, Ericsson, Ward, & Eccles, 2008; Williams & Reilly, 2000).

Expertise is generally defined as the ability of an individual to consistently demonstrate superior levels of proficiency within a particular domain over an extended period of time (Starkes, 1993). The word *expert* originally comes from the Latin experiri, which is a derivative of the word experience (i.e., having experience of). The original conceptualisation of expertise was generally accepted/viewed as the product of superior general intelligence and innate talent (e.g., Galton, 1869), until the pioneering and classical work of de Groot (1965). De Groot (1965) explored differences in memory processes between master and amateur chess players by presenting them with chess positions for a 2-15 s time lapse and then removing them from view. The master chess players were able to recall and reconstruct the locations of the chess pieces, achieving scores of almost 100% accuracy for positions containing about 25 pieces. Chase and Simon (1973) replicated and extended de Groot's (1965) work and proposed the first theory of expertise based on the framework of human information processing (Newell & Simon, 1972). In this study, they asked master and novices chess players to recall both game-related and randomised configurations of pieces on a chessboard (see Figure 1.1). The masters were only able to accurately recall chess pieces in the game-related condition, whereas no skill-based differences were apparent for the random condition. The results proposed that the highest levels of mastery are associated with a player's ability to retrieve appropriate moves from a large repertoire of board patterns (i.e., an extensive domain-specific knowledge base). The chess masters were able to recall and encode 15 to 30 chess pieces in structured formations into more complex chunks, allowing them to circumvent the limits of human information processing (e.g., 7 ± 2 storage pieces of information in short-term memory, cf. Miller, 1956). The lack of skill-based effects on the randomised chess pieces provided evidence that players do not possess superior general memory skills (see Ericsson & Charness, 1994). Other scientists have subsequently demonstrated a close relationship between immediate recall of structured game positions and superior expert performance across various sporting contexts (for a review, see Starkes, Helsen, & Jack, 2001; Williams, Davids, & Williams, 1999).

(a) (b)

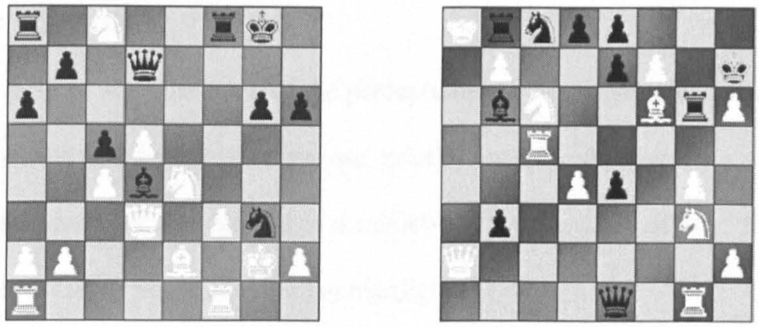


Figure 1.1. Types of positions typically presented in chess research on superior memory using (a) actual game positions and (b) random chessboards.

In their classic study, Simon and Chase (1973) argued that 10-year period of intense practice and engagement is needed to reach the level of a grandmaster in chess and suggested similar prerequisites in other domains. Ericsson, Krampe, and Tesch-Römer (1993) showed support for the '10 year rule', suggesting that at least 10 years of intensive preparation, which corresponds to several thousands of hours of practice, would be necessary to acquire the complex mechanisms that sub-serve expertise in any domain. Ericsson and colleagues (1993) proposed that the factors associated with innate talent are unlikely to be the most crucial ingredient in the recipe for success. The more important factor appears to be sustaining commitment and engagement in high amounts and specific types of practice activities throughout, providing aspiring athletes the essential adaptive learning and explicit perceptual-cognitive and motor acquisition processes on the road to excellence (Ford, Hodges, & Williams, in press). Yet, no defined theoretical framework can accurately explain and predict expertise. It therefore becomes necessary to explore and determine the characteristics of these adaptive learning and underlying processes and mechanisms by conducting more descriptive research to help inform the development of such a model (Ericsson, 2003b).

In the next sections some of the perceptual-cognitive adaptations that occur as a result of practice and experience are briefly considered. Moreover, the expert performance approach is presented as a framework for the study of expertise and the aims of current programme of work are highlighted.

Perceptual-Cognitive Expertise

In recent years, there has been considerable interest in exploring the nature of perceptual-cognitive expertise across a range of domains (for a review, see Williams, Ford, Eccles, & Ward, 2011). Marteniuk (1976) defined *perceptual-cognitive skill* as the ability to identify and acquire environmental information for integration with existing knowledge to facilitate selection of the appropriate response to be executed. In sport, one of the more significant adaptations results in the development of perceptual-cognitive skills and processes involved when making anticipation (i.e., the ability of a performer to predict what is likely to happen prior to an event occurring) and decision making (i.e., the ability of the performer to select and execute an appropriate action in a given situation) judgments during performance. These adaptations are deemed to be essential in team ball sports, such as soccer, because of the time constraints and dynamic speed of play, which often goes beyond the elementary constraints imposed by the player's basic information processing capacity (Williams et al., 1999; see also Chapters 3 and 4). Moreover, in soccer, the ability to anticipate and make decisions is thought to be highly important at the elite level, where these particular components of performance are more likely to differentiate players when compared to physical and physiological factors (Williams & Reilly, 2000).

According to Wickens (1992), experts demonstrate superior anticipation and decision making over novices on the basis of three factors. First, experts are able to pick up the most relevant cues from the environment based on a more efficient processing system or chunking of information in a format that facilitates memory. Second, they have a superior repertoire of action-goal concepts and a greater knowledge base of situational probabilities stored in long-term working memory. Finally, they exhibit a greater coupling between cue perception/recognition, probabilities formation, and decision making response outcomes than their less skilled counterparts. In this section an overview of some of the key perceptual-cognitive adaptations and skills is provided in order to illustrate the importance of these components to performance (see also Chapter 4).

Advance cue utilisation. This skill refers to a player's ability to pick up early visual information from an opponent or teammate's postural orientation (i.e., advance postural cues) ahead of a key event such as a foot-ball contact (Franks & Hanvey, 1997; Savelsbergh, Williams, van der Kamp, & Ward, 2002; Williams & Burwitz, 1993). The expert's ability to process advance visual cues has been shown in goalkeepers as well as outfield players in soccer (Williams & Davids, 1998). This issue has typically been examined using filmed-based occlusion techniques. For example, Williams and Burwitz (1993) had experienced and inexperienced soccer goalkeepers observing filmed sequences of different players executing a series of penalty kicks while using an eye-movement recording system. The film clips included four different temporal occlusion conditions (i.e., 120 and 40 ms before the player kicked the ball, at impact and 40 ms after impact) in order to determine cue usage by the participants. The most important sources of information used by experienced goalkeepers included the position of the penalty-taker's hip and the angle of the trunk and foot prior to ball contact (see also Savelsbergh, van der Kamp, Williams, & Ward, 2005; Savelsbergh et al., 2002).

A more recent proposition is that the advantage of skilled performers on such situational tasks may be due to their greater attunement to biological motion information, as opposed to the ability to fixate upon particular cue sources (Ward, Williams, & Bennett, 2002). This ability ensures that experts are less prone to situations where deceptive movements are applicable in comparison with less skilled counterparts. Thus, the effective pick up of relative motion in fast ball sports enable athletes to prepare in advance and execute their own response in order to counter the intentions of an opponent or correct a potential inaccuracy of a teammate.

Pattern recognition. In dynamic team sport ball games, such as soccer, the ability to recognise familiarity and structure in an evolving pattern of play early in its development is presumed to be an important component of anticipation. The seminal research demonstrating the expert's superior pattern recognition ability on traditional 'recall' and 'recognition' paradigms was conducted in chess by de Groot (1965) and then extended by Chase and Simon (1973) (as discussed above). More recently, there have been attempts to better identify the processes underpinning the recognition of structured sequences and its relation with anticipation and decision making in sports (e.g., North, Williams, Hodges, Ward, & Ericsson, 2009; Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor, 1996; Williams, Hodges, North, & Barton, 2006). For example, in soccer, North et al. (2009) presented participants with a series of clips showing attacking patterns of play from various soccer matches in film or point-light display format and recorded their eye-movements. In a subsequent phase, participants were required to recognise previously viewed sequences. Skilled players were more sensitive in discriminating previously viewed and novel clips (regardless of presentation format) than less skilled counterparts. Skilled players also fixated more locations than less skilled players, implying that they may recognise and process dynamic scenes as a series of structural relations between task-relevant features within the display (e.g., relational information between players).

It appears that expert sport performers display similar recognition and recall skills as masters in chess and experts in other domains. The presumption is that expert performers combine low-level relational information and temporal relationships between features (e.g., teammates, opponents, the ball), before matching this information with higher-level cognitive processing of concepts/templates of potential scene formations stored in memory (Dittrich, 1999; Dittrich & Lea, 1994). In contrast, less skilled performers have fewer internal semantic concepts and so processing is unrefined and based primarily on the recognition of superficial, low-level surface features (e.g., background information, isolated distinctive actions).

Visual search behaviours. The superior ability of experts to pick up postural information cues and to recognise patterns of play is due partly to quantitatively different and more effective visual search behaviours. Experts systematically demonstrate differences compared with novices on key visual components such as number of fixations, fixation duration, and the proportion of time spent fixating on different locations/areas on the display (e.g., Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007a, b; Williams & Davids, 1998; Williams, Davids, Burwitz, & Williams, 1994; Williams, Janelle, & Davids, 2004). For example, visual search strategy was examined by Williams et al. (1994) who required participants to anticipate ball direction using 11 versus 11 soccer film sequences presented on a large video projection screen. The inexperienced players fixated more frequently on the ball and the player passing the ball, whereas the experienced players fixated more on the positions and movements of opponents by employing a search strategy involving more fixation locations and of shorter duration. Thus, a key difference between experienced and less experienced soccer players appears to be their ability to more extensively search the display and pick up useful visual information in advance to guide performance. There is also evidence to suggest that experts' search strategies adapt more effectively to the changing demands of the situation or task and are less affected by changes in emotional states, such as psychological stress and anxiety (see Williams & Elliott, 1999; see also Chapter 4).

Situational probabilities. In addition to the ability to extract task-specific contextual information present within the display as the action unfolds, experts are more accurate in formulating 'a priori' expectations/probabilities of the potential options that might happen for each situation (e.g., what an opponent is likely to do in advance of any actual given event). These expectations or situational probabilities may be more general in nature, applicable in a variety of situational scenarios involving different teams and players, or more specific to a particular team, player, or opponent(s). Also, the performer's a priori expectations may be confirmed or modified as the action unfolds. The importance of this cognitive component or ability in soccer was demonstrated empirically in a study by Ward and Williams (2003). In this study, participants were presented with filmed sequences of match-play situations that were frozen at key moments in action. Participants were required to highlight and rank in order of likelihood the key players in a good position to receive the ball. As expected, elite players chose a greater number of likely event probabilities and were better able to rank the options in order of threat to the defence.

In contrast, sub-elite players were less proficient in assigning a hierarchy of probabilities to the events likely to unfold. The proposal is that experts enhanced domain-specific knowledge structures permit them to dismiss a range of situations considered as being highly unlikely (Gottsdanker & Kent, 1978).

Memory. An important issue that arises from this section is that players adapt to the specific constraints of the performance environment. In an advance to the limited general theory of expertise by Simon and Chase (1973), that necessitates the working-memory demands of processing had to be managed within the fixed limits of short-term memory capacity (for a review, see Ericsson, Patel, & Kintsch, 2000), Ericsson and co-workers (e.g., Ericsson, 1998; Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995) proposed the long-term working memory (LTWM) theory to explain the domain-specific perceptual-cognitive adaptations that occur as a result of extended practice within the domain. The suggestion is that expert performers bypass the customary limitations imposed on short-term working memory by acquiring complex and sophisticated skills that allow rapid and reliable encoding of information in long-term memory and enable selective access to this information when required. With extended practice within the domain, experts index information in an efficient way such that complex retrieval structures in long-term memory can be easily accessible by means of cues in short-term memory. This extension of memory provides performers with greater competence to engage in high-level processing such as planning, reasoning, evaluation, and other cognitive processes deemed crucial to expert performance (see Ericsson & Delaney, 1999).

Expert Performance Approach

In response to some growing criticisms of the original general theory of expertise, Ericsson and Smith (1991) proposed the *expert performance approach* as a new guiding framework for the study of complex integrated behavioural phenomena. Three distinct phases/stages in the empirical and inductive analysis of expertise and expert performance were introduced as illustrated in Figure 1.2. In the first stage, researchers study the naturally observable expert performance to capture the essence of expertise in the sport of interest and to identify the representative tasks that would allow component skills to be faithfully reproduced in the laboratory or field setting. In the second stage, the aim is to determine the underlying mechanisms that mediate expert performance on the task, using process-tracing measures such as eye-movement recordings, verbal protocol analysis, and/or representative task manipulations. Finally, once researchers identify the mediating mechanisms that account for expert performance, they can then assess and determine how experts acquire and develop the component skills needed to demonstrate reliably superior performance (i.e., the adaptive learning and acquisition processes). The current thesis uses this framework as a structure for examining perceptual-cognitive expertise in soccer and its acquisition.

DIAGRAM
ON THIS PAGE
EXCLUDED
UNDER
INSTRUCTION
FROM THE
UNIVERSITY

Figure 1.2. An illustration of the expert performance approach and some of the methods and measures that may be used at each stage[1].

Capturing perceptual-cognitive expertise. The initial phase of the expert performance approach challenges researchers to capture the naturally observable essence of expertise and its component skills in a particular domain. To achieve this, well-designed representative tasks that provide effective and reproducible measures of superior performance under standardised laboratory/field setting conditions are used. In order to increase the possibility of identifying critical differences between expert and less skilled performers, testing should be carried out under controlled situations that replicate the performance environment as closely as possible (Abernethy, Thomas, & Thomas, 1993; Williams & Ericsson 2005). Since the purpose is to monitor and examine processes that have been adapted throughout extended years of practice, performance on these tasks should not vary significantly over the replication of tests.

[1] Reprinted from Human Movement Science, 24, Williams, A. M., and Ericsson, K. A., Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach, p. 286, 2005.

Although the design of well controlled and reproducible experiments with good ecological and external validity has always been a challenge for scientists, the tendency has been to develop simplistic or contrived tasks, particularly in the domain of sport given the dynamic, temporal constraints, and emotional and complex motor-action demands of the performance (for a review, see van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). The removal of key elements and environmental constraints from the stimulus display may force performers to use processes which they do not normally use to solve a task, reducing the possibility of identifying the specific and complex processes that mediate truly expert performance (Dicks, Davids, & Button, 2009; Williams & Ericsson, 2005). Additionally, sport researchers most often select and examine one single discrete task for scrutiny, such as, for example, the interception of a penalty kick in soccer, the basketball free throw, or the serve in tennis (e.g., Dicks, Davids, & Button, 2010b; Oudejans, van de Langenberg, & Hutter, 2002; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996). There is a need for further investigation into the complex dynamics of open-play situations in order to provide a more complete representation of the underlying mechanisms and adaptations that occur in sport (de Oliveira et al., 2009).

A number of researchers interested in perceptual-cognitive expertise have focused on anticipation ability only where they generally have participants sitting down and instructed to anticipate the final action before occlusion of display (see Huys et al., 2009; North, Ward, Ericsson, & Williams, 2011; Weissensteiner, Abernethy, Farrow, & Müller, 2008; Williams, Ward, Ward, & Smeeton, 2008). In continuous and dynamic open-play sports, players need to select and execute actions (i.e., decision making ability). Therefore, the lack of (physical) realism and intention to only anticipate in sport domains where anticipation and decision making are mutually part of performance (e.g., team ball sports), might alter the natural role of the underlying processes of perceptual-cognitive expertise (Abernethy et al., 1993). Research is needed to examine the influence of methodological factors on performance. These methodological and procedural issues are examined and discussed in Chapter 2.

Identifying the perceptual-cognitive processes that mediate expert performance. The second phase of the expert performance approach seeks to assess the mediating mechanisms that account for superior performance. After a representative task(s) have been developed that effectively captures the essence of perceptual-cognitive expertise within the domain (i.e., first stage of the expert performance approach), the aim is to apply a range of process-tracing measures and task manipulations to identify the specific processes and mechanisms underlying the expert performance. Two typical paradigms are normally used at this stage including expert-novice comparisons (so far the more widely applied approach in sports) and singe subject case studies of experts. Williams and Ericsson (2005) state that this particular stage of the expert performance approach is often ignored by scientists who generally tend to simply identify differences in performance across skill levels. Some examples of techniques that may be employed to identify mediating processes include eye-movement recording, film occlusion, point light displays, biomechanical profiling and data reduction techniques, neurobiological and psychophysiological measures of selective attention, and verbal protocol analysis (e.g., Abernethy, 1990; Helsen & Starkes, 1999; McPherson, 1999; Radlo, Janelle, Barba, & Frehlich, 2001; Williams et al., 2006).

In the domain of team ball sports such as soccer, a number of researchers have examined the visual search behaviours employed by skilled and lesser skilled/experienced outfield players, goalkeepers, as well as referees during performance in an attempt to gain new insights into the nature of perceptual-cognitive expertise (e.g., Catteeuw, Helsen, Gilis, Van Roie, & Wagemans, 2009; Salvesbergh et al., 2002; Vaeyens et al., 2007a, b; Williams & Davids, 1998). However, visual search data from these studies only indicate the perceptual sources of information used by performers to guide their action. A lack of research exists that has examined the cognitive processes mediating exceptional performance of athletes on the task. Verbal report protocols may offer a window into how performers translate the information scan/perceived from the visual display into appropriate decisions, providing greater insight into the important processes that mediate (and interlink) perception and decision making (Williams & Ericsson, 2005).

Additionally, researchers attempting to examine the importance of the different perceptual and cognitive skills (e.g., advance cue usage, pattern recognition, and situational probabilities) have done so generally using paradigms that examine these skills in isolation from the others (e.g., North et al., 2009; Williams & Burwitz, 1993; Ward & Williams, 2003). It is suggested that the relative importance of these perceptual-cognitive skills may interact in a dynamic and evolving manner based on a range of constraints related to the task, situation, and performer (see Williams, 2009; see also Chapter 4) (see Figure 1.3). It is therefore plausible that researchers may have overemphasised the importance of some of these skills to actual performance. Further exploration of these issues is clearly warranted (cf. Williams & Ward, 2007), perhaps using different process-tracing measures in combination with representative situational-task manipulations (e.g., manipulate ball distance relative to the performer(s) in team invasion ball sports). These questions are addressed in some detail in Chapters 3 and 4.

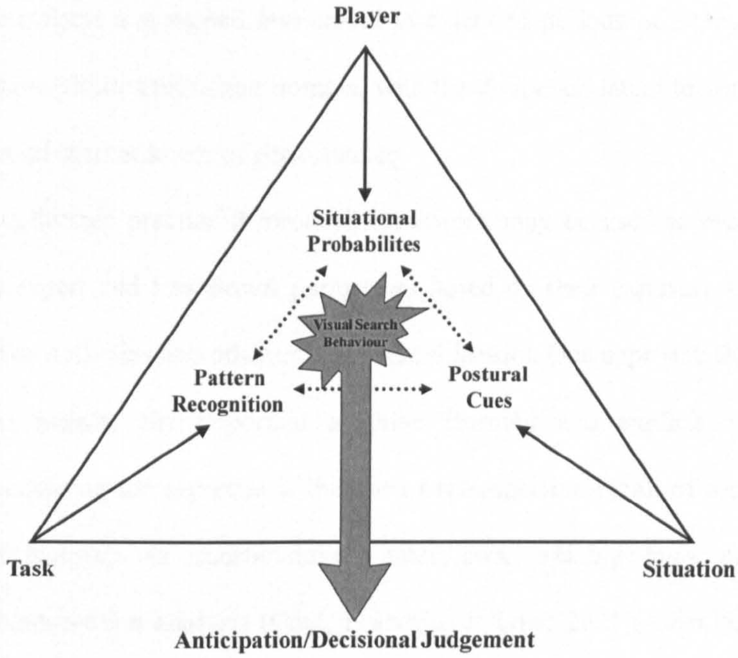


Figure 1.3. The potential interactive relationship between various perceptual-cognitive skills and constraints when making anticipation/decisional judgements[2].

Examining how the mediating perceptual-cognitive processes are acquired. The final stage of the expert performance approach entails efforts to determine the adaptive learning and acquisition processes that have caused adaptations to the mechanisms underpinning expert performance. A better understanding of how experts acquire the skills and processes needed to demonstrate reliably superior performance might provide important sources of information with potential implications for the practice/learning and instructional processes. Researchers in this phase have tended to rely on Ericsson et al. (1993) deliberate practice framework. The central claim of this framework is that exceptional

[2] Reprinted and adapted from Progress in Brain Research, 174, Williams, A. M., Perceiving the intentions of others: How do skilled performers make anticipation judgments? p. 80, 2009.

performance reflects a sustained investment in extended periods of intense training and preparation within a particular domain, with the deliberate intent to continuously improve beyond current levels of performance.

The deliberate practice theoretical framework may be used to examine and discriminate expert and less expert performers based on their exposure to specific type of practice activities and other environmental factors. One approach that may be employed to identify the important adaptive learning and explicit acquisition processes accounting for expertise is the use of retrospective recall of the athletes' participation history, via questionnaires, interviews, training logs, and video observation/time-motion analysis (Côté, Ericsson, & Law, 2005 ; Deakin, Côté, & Harvey, 2006; Ford, Yates, & Williams, 2010b). Thus, the deliberate practice framework may be applied to help identify the type and specificity of practice-related activities that players engage in across different stages of their development towards expert performance in adulthood. On the other hand, the validity of these practice activities may be confirmed through more traditional experimental designs in the laboratory (e.g., perceptual-cognitive video simulation test).

There have been recent attempts to examine the relationship between antecedent practice activities and perceptual-cognitive components of performance, such as anticipation skill in cricket batting (e.g., Ford, Low, McRobert, & Williams, 2010a; Weissensteiner et al., 2008). Ford et al. (2010a) examined this relationship by stratifying 45 elite cricket batters into high- and low-performers based on anticipation performance on a traditional, film-based temporal occlusion test. Questionnaires were used to record the participation history profiles of the players. In the early stages of development, hours accumulated in cricket and other sports, as well as milestones achieved, did not differentiate groups. Significant differences in activity profiles only emerged between 13 and 15 years of age, with high-performing anticipators accumulating more hours in structured cricket activity and batting, compared with their low-performing counterparts. Researchers have mainly looked at the athletes' antecedent practice activities that contribute to the development of anticipation (e.g., Ford et al., 2010a; Weissensteiner et al., 2008), whereas there is a need to examine the acquisition of other perceptual-cognitive components or skills. MacMahon, Helsen, Starkes, & Weston (2007), for example, examined decision-making skills and their relation to deliberate practice patterns in elite soccer referees. Results suggested that these skills developed primarily through competitive (league) match refereeing. It is likely that a (soccer) player's ability to demonstrate superior performance on a task is made up of several components, such as anticipation, strategic and tactical decision making, and technical skill. Some of these issues are considered in Chapter 5.

Aims of the Thesis

There is a lack of literature providing a more holistic and integrated analysis of perceptual-cognitive expertise and its acquisition in highly dynamic and externally paced sports, such as soccer. The intrinsic demands of soccer are formed by the continual transition from macro to micro states of play, involving varying numbers of players, and the constant need to preserve a balance between defensive and offensive duties. To this end, there is the need for researchers to attempt to capture and examine the complexity of the continuous perception and decision making that occurs during game play. To achieve this, researchers should use the most realistic simulation environment possible whilst ensuring controlled and reproducible conditions. Previously, researchers examining the underlying processing and component skills of perceptual-cognitive expertise and how these are acquired have mainly focused on anticipation skill. In soccer, decision making (i.e., what will I do in this situation) is at least as important as anticipation (i.e., what will my opponent do) during performance. Therefore, there is a need to examine anticipation *and* decision making in combination with process-tracing measures (i.e., eye-movement recording and verbal protocol analysis) and measures of their acquisition. Moreover, in previous research the perceptual-cognitive skills (i.e., advance cue usage, recognising patterns, and situational probabilities) that are thought to play a crucial role in anticipation and decision making have been examined in isolation (Williams & Ericsson, 2005). These perceptual-cognitive skills are likely to interact with one another during actual performance as function of the unique constraints of the game, and their interaction has yet to be identified adequately (cf. Williams & Ward, 2007).

The aim of the present thesis is to extend knowledge and provide a greater understanding of how (outfield) players anticipate and make decisions in the dynamic, externally paced tasks of soccer and how these abilities are acquired. The research programme will use the three stages of the expert performance approach (Ericsson & Smith, 1991) as a guiding framework. In the first phase, an attempt will be made to develop, employ, and validate a realistic and representative test of anticipation *and* decision making in soccer whilst maintaining controlled and reproducible conditions in the laboratory. In the second phase, the test will be used in an attempt to extend understanding of the processes underpinning the ability to anticipate and make decisions in soccer situations. In the final stage, an attempt is made to identify the specific types of practice activities and/or strategies that lead to the acquisition and development of anticipation and decision making.

In the first study (Chapter 2), a valid and reliable task is created to examine perceptual-cognitive expertise in soccer in order to capture reproducible superior performance under standardised laboratory conditions. In Experiment 1, retrospective verbal reports of thinking are collected across skilled participants during two conditions that differ in fidelity: non-movement (as per the majority of previous research on anticipation in sport) and movement simulated response conditions. In Experiment 2, an attempt is made to provide construct validity for the experimental paradigm (from Experiment 1) by examining the anticipation and decision making responses of skilled and lesser skilled players. It is expected that differences in the experimental settings' fidelity would lead to differences in the cognitive processes underlying performance. Specifically, participants in the movement group will provide a greater number of verbal reports demonstrating a higher-order of cognitive processing when compared with the non-movement group. Also, it is predicted that skilled participants in Experiment 2 would make more accurate anticipation and decision making responses than less skilled counterparts, which would provide construct validity for the representative soccer task simulation.

In Chapters 3 and 4 (Studies 2 and 3, respectively), the second stage of the expert performance approach is addressed by examining the underlying processes of anticipation and decision making using/combining eye-movement recording (Experiments 3 and 5) and verbal reports of thinking (Experiments 4 and 6). This research will provide a more detailed and complete analysis of the mechanisms underpinning the expert's superior performance compared to the less skilled. In addition, a novel approach using the manipulation of specific and distinct situational task constraints (i.e., ball distance relative to the participant/player) is employed in Chapter 4. The rationale for this manipulation is to examine for the first time in the literature whether and how the different perceptual-cognitive skills (e.g., postural cues, pattern recognition, and situational probabilities) interact during performance.

It is predicted that the superior performance of skilled participants would be caused by systematic differences in the underlying perceptual and cognitive processes when compared with the less skilled participants, and that variation will be found as a function of the situation and task (i.e., far vs. near). It is further expected that the different perceptual-cognitive skills will reveal a dynamic interaction with each other during performance, with their relevance altering considerably from one situation to the next.

In Chapter 5 (Study 4), an attempt is made to determine how skilled soccer players acquire their anticipation and decision making ability. Soccer players who are classified as high- or low-performing (based on their scores on the soccer-specific test that evaluates their ability to anticipate and make decisions) will be compared on the specific type and amount of practice activities that they have engaged in during their development. Participation history profiles of players are recorded using retrospective recall questionnaires. It is expected that hours spent in soccer-specific play activity during childhood will be the strongest predictor of superior anticipation and decision making performance across groups and participants.

In the final Chapter 6 the findings from this research programme are synthesised in order to provide a general and concise summary of both the theoretical and applied implications of the thesis. Potential limitations of the programme of work are discussed and future research directions drawn from the key findings.

Chapter 2

Capturing and Testing Anticipation and Decision Making Expertise

Abstract

The aim of this chapter is to develop and validate a representative task to measure anticipation and decision making ability in soccer. In Experiment 1, two representative simulation task conditions are compared: verbal and movement responses. Skilled participants either stayed in a seated position and verbally responded (n = 10) or were allowed to move (n = 10) in response to life-size film sequences of 11 versus 11 open-play soccer situations filmed and viewed from the perspective of a central defender. Response accuracy and retrospective verbal reports of thinking were collected across participants during the two task conditions. Participants for the movement condition generated a greater number of verbal report statements, including a higher proportion of evaluation, prediction, and action planning statements than the participants for the non-movement condition. In Experiment 2, anticipation and decision making were assessed across a group of skilled (n = 10) and less skilled (n = 10) soccer players in an attempt to validate the experimental paradigm (from Experiment 1) to be used in future experiments in the current research programme. The skilled participants were significantly more accurate at anticipation and decision making compared with their less skilled counterparts (Experiment 2). The data suggest that information processing strategies function differently, depending on the representative design of the experimental task constraints. Implications for experimental design are discussed.

Keywords: *expertise, representative task design, fidelity, construct validity*

The key challenge for scientists applying the expert performance approach proposed by Ericsson and Smith (1991) is to identify the essence of superior performance in a domain and design representative tasks that allow its measurement. Using representative tasks, researchers can further measure the processes that mediate expert performance under controlled and reproducible conditions. Attempting to faithfully capture and reproduce component skills in ball games provides problems for researchers because of the dynamic and rapidly changing nature of these sports (for a recent overview, see van der Kamp et al., 2008). In this chapter, an attempt is made to develop and validate a dynamic and externally paced soccer task using the most realistic simulation of that environment that is possible under standardised and controlled conditions in the laboratory.

Although the majority of researchers have attempted to conduct high fidelity (i.e., the degree to which a model or simulation reproduces the state and behaviour of a 'real-world' feature or condition; see Hays & Singer, 1989) and representative experiments, the tendency, due partly to the difficulties mentioned above, has been to design simplistic and sometimes manufactured tasks that overemphasise experimental control (Dhami, Hertwig, & Hoffrage, 2004). These designs may introduce potential floor and/or ceiling effects on the expert's performance advantage, forcing them to use processes which they do not normally use to solve a task (Abernethy et al., 1993). Only when it has been possible to create a representative task that accurately measures reproducibly superior performance within a specific domain can one proceed to the following phase of the expert performance approach in an attempt to effectively identify the processes and component skills underpinning perceptual-cognitive expertise (Ericsson, 2003b).

The fidelity of experimental paradigms has been shown to cause significant differences in performance (Mann, Abernethy, Farrow, 2010) and perceptual-cognitive processing behaviours (Dicks, Button, & Davids, 2010a). Mann et al. (2010) had cricket batters of different skill level undertaking four different counterbalanced response conditions of increasing functional fidelity (i.e., verbal, lower-body movement only, and full-body movement without and with bat response) to the direction of balls bowled towards them. The superiority of experts over novices in prediction accuracy was reported to increase as a function of the enhanced ecological representativeness of the task condition. In the study by Dicks et al. (2010a), gaze behaviours of association soccer goalkeepers were compared in response to penalty kicks under two video simulation conditions (i.e., verbal and joystick movement responses) and three in situ conditions (i.e., verbal, simplified body movement, and interceptive response). The experienced goalkeepers demonstrated differences in gaze behaviours for information detection between experimental conditions. The most pronounced difference was that goalkeepers fixated earlier and for longer duration on the ball location in the most representative condition (i.e., interceptive movement responses) compared to those involving verbal responses or limited movement, which is comparable with previous results in studies of perceptual expertise using more realistic scenarios (see Vickers, 2007). Similarly, in another study Mann, Farrow, Shuttleworth, and Hopwood (2009) reported that expert soccer players made fewer visual fixations of longer duration in a more realistic 'player' perspective (i.e., video footage shown from ground level in which the participants imagine they are one of the players on the screen) compared with a third-person 'aerial' perspective (i.e., footage filmed from a slightly elevated position). The different viewing perspectives (i.e., aerial vs. player) did not affect the amount of time spent fixating the player in possession of the ball. However, they reported that players spent a greater amount of time fixating areas of 'free space' in the aerial perspective, whereas more time was spent fixating opponents and teammates in the player perspective.

The majority of researchers examining perceptual-cognitive skill and its underlying processes have focused on anticipation judgments (i.e., what the participant thinks an opponent will do, see North et al., 2009; Savelsbergh et al., 2005: Williams, Ward, Knowles, & Smeeton, 2002), with relatively few attempts to measure decision making (i.e., how the participant would respond; for exceptions, see Helsen & Starkes, 1999; Vaeyens et al., 2007a, b). Although both anticipation and decision making are considered as being crucial in dynamic, time-constrained tasks across a range of team ball sports like soccer (Williams & Ward, 2007), there have been few, if any, well-controlled efforts to integrate and examine both judgments simultaneously. North et al. (2009) showed that when participants are only required to anticipate what will happen next in a situation, the underlying processes (e.g., number of fixation locations) differ compared with when they are required to recall situations, suggesting that different mediating processes underpin these two types of judgments. It is conceivable that different perceptual and cognitive processes may be employed when athletes are required to both anticipate and make decisions concurrently in comparison to when each judgment is measured and performed in isolation. Although no direct statistical comparisons are conducted in this study, an attempt is made to incorporate both measures of performance in order to best replicate the demands of the real-world performance environment.

Furthermore, the overriding tendency of scientists in the domain of sport has been to examine single isolated closed tasks or skills (e.g., soccer penalty kick, tennis/squash serve, and basketball shooting/free throw). In reality, many sports involve highly dynamic, open, and complex situations and the challenge is to design experimental tasks that replicate these situations. Although the processes underlying expert performance may be similar between closed and open sports tasks, there remains a need to examine these processes in more open-play tasks. Experiments that can capture the complexity and continuous underlying processes of anticipation and decision making that occurs during open sports game play are clearly warranted (de Oliveira et al., 2009). In addition, the majority of experiments (e.g., North et al., 2009; Ward & Williams, 2003; Williams et al., 1994) examining anticipation in expert athletes have had participants sitting still watching representative video footage rather than moving and interacting with the stimuli as they would do in reality. Given the differences in performance (Mann et al., 2010) and perceptual processes (Dicks et al., 2010a) found between movement and non-movement conditions, it is likely that there will be differences in the cognitive processing strategies. The challenge for scientists is to design and employ task-paradigms that provide precise and reproducible domain-specific situations so that performance can be objectively evaluated over repeated tests (Araújo, Davids, & Passos, 2007; Dicks et al., 2009; Pinder, Davids, Renshaw, & Araújo, 2011).

The aim in this chapter is to create a valid and reliable representative task to examine perceptual-cognitive expertise in soccer in order to capture reproducible superior performance under standardised laboratory conditions. A representative film-based simulation test of 11 versus 11 open-play soccer situations from a player's perspective is presented. In Experiment 1, retrospective verbal reports of thinking are collected from skilled participants during two conditions that differ in fidelity: non-movement (as per the majority of previous research on anticipation in sport); and movement simulated response conditions. In Experiment 2, measures of performance are used across participants of different skill level in an attempt to provide construct validity for the experimental paradigm (from Experiment 1.

Experiment 1

Previous research has demonstrated that perceptual processes change under task conditions that differ in fidelity (e.g., Dicks et al., 2010a; Mann et al., 2009; North et al., 2009). Experiment 1 compared the cognitive processes of skilled soccer participants under two different video simulation task conditions (i.e., non-movement and movement condition), as well as their anticipation and decision making performance. The fidelity of the soccer task is predicted to be lower when participants are seated in the non-movement condition (which has generally been the norm in experiments such as these) compared to the movement condition. It was expected that this difference in fidelity would lead to verbal reports of underlying cognitive processes to differ between the two task manipulations (i.e., movement and non-movement simulation constraints). Specifically, it was predicted that a higher number of verbal reports representative of a higher-order of cognitive processing (e.g., predictions, action planning) would be generated under the movement compared with the verbal response task constraint due to the potential higher representativeness of the environment stimuli and fidelity associated with the movement task condition (Araújo et al., 2007; Dicks et al., 2009). For this same reason, it was also hypothesised that participants in the movement group would demonstrate superior performance scores in comparison with their counterparts in the non-movement group (e.g., Mann et al., 2010).

Methods

Participants

In total, 20 adult male semi-professional soccer players participated in the experiment. Participants were randomly allocated into two different experimental groups: movement (n = 10) and non-movement (n = 10). The movement group took part in a more realistic representative task that included an action component, whilst the non-movement performed a less realistic task (i.e., in a seated position). The participants in the movement group (M age = 21.5 years, SD = 2.0) had played soccer regularly since the mean age of 5.6 years (SD = 1.2), during which they had trained/played for a mean of 9.2 hr (SD = 1.7) per week and participated in an average total of 615 (SD = 131) competitive matches. The non-movement group (M age = 21.1 years, SD = 2.0) had regularly participated in soccer since the mean age of 5.8 years (SD = 1.6), during which they had trained/played for a mean of 9.0 hr (SD = 1.8) per week, including participation in an average total of 632 (SD = 145) competitive matches. Informed consent was provided prior to participation and ethical approval was gained through the lead institution's Ethics Board.

Test Film

Participants were presented with life-size video sequences involving dynamic, 11 versus 11 soccer situations filmed from the first-person perspective of a central defender (i.e., a sweeper; see Figure 2.1). The action sequences were filmed on a regular soccer pitch using a wide-angle converter lens (Canon WD-H72 0.8x, Tokyo, Japan) attached to a high-definition digital video camera (Canon XH A1s, Tokyo, Japan). The camera was positioned in an elevated position (approx. 2.75 m) near the penalty spot in the defending team's penalty area. The filming perspective enabled the entire width of the playing field to be viewed, as well as helping with the perception of depth. Furthermore, the perspective provided a realistic correspondence with the field of view that a central defensive player normally observes when playing in a match. A panel of three Union of European Football Associations (UEFA) qualified soccer coaches determined the content and structure of the video clips to be captured by designing a large number of realistic 11 versus 11 offensive patterns of play. The filming included 11 versus 9 (the defensive team's sweeper and goalkeeper were not involved) skilled adult players in full team kits who received detailed instruction and rehearsal over a 3-week period. The footage was then digitally edited using Adobe Premiere Pro CS4 software (Adobe Systems Incorporated, San Jose, CA, USA) to construct a number of short clips to be used in the anticipation and decision making simulation task. Subsequently, the soccer coaches independently selected the video simulation clips to ensure that each one was representative of actual game play. Only the action sequences approved unanimously by the coaches were included in the test film.

The final test film consisted of 20 test and four practice trials. At the start of each video clip stimulus, a red dot appeared on a black background to indicate where the ball would be located at the start of the action sequence. Such a procedure enabled participants to be aware of where the ball was from the outset of the clip, thus stopping them conducting a search for it during the opening frames of the video clip as per previous research (e.g., North & Williams, 2008). This procedure was followed by a photograph of the first frame of the clip to allow participants to identify their teammates and the opposing team, as well as their positions on the field. The panel of coaches deemed this orientation necessary because players in a soccer match are always aware of the position of the ball, and to some degree where their teammates/opponents are, during play. The still image was visible for approximately 1.5 s before the video commenced. The video clips each lasted approximately 5 s, with each one being occluded 120 ms prior to the player in possession of the ball making a key attacking pass, shooting at goal, or maintaining possession of the ball by dribbling forward. Each video clip ended with a white screen in order to prevent the participants from receiving any information from the last frame when the clips were occluded.

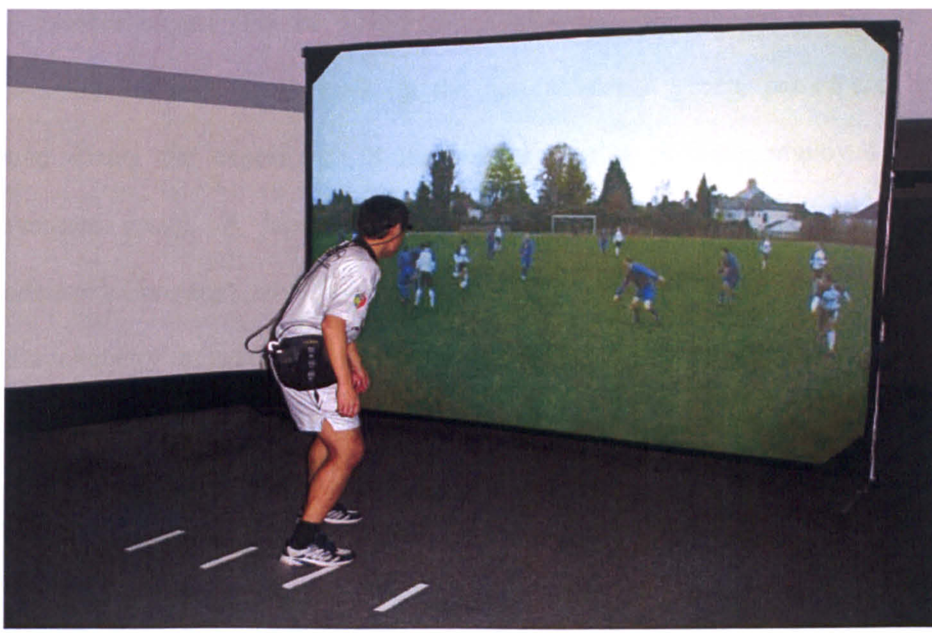


Figure 2.1. The experimental setup and the perceptual-cognitive soccer representative task simulation (i.e., movement task condition).

Apparatus

The film clips were back projected, using a 3LCD video projector (Hitachi ED-A101, Yokohama, Japan) with XGA resolution onto a 2.7 m (h) x 3.6 m (w) large projection screen (Draper Cinefold, Spiceland, IN, USA). Participants stood central 2.5m away from the screen affording them a typical viewing angle of around 35° and 28° degrees in the vertical and horizontal planes, respectively. This set up provided a realistic environment closely simulating the real image size and distance between the player (i.e., in a central defensive position) and the action. Participants in the movement group were free to move and interact with the action sequence as they would normally do when playing in a real soccer match (e.g., moving forward, backwards, sideways, closing down, opening their body) (see Figure 2.1). The movement of participants were monitored using a digital video camera (Canon LEGRIA FS200, Tokyo, Japan) positioned 3m behind the participant and linked to a TV monitor screen (Philips 15PF5120, Eindhoven, Netherlands) placed on the experimenter's desk. In contrast, in the non-movement group, participants were seated during the experiment at the central starting position employed in the movement group. A lapel wireless microphone set (Sennheiser EW-100G2, Wedemark, Germany), including a telemetry radio transmitter fixed to the participant and a telemetry radio receiver connected to the digital video camera, was employed so as to collect verbal reports.

Procedure

Prior to testing, participants received instruction and training on how to think aloud and provide retrospective verbal reports. These instructions comprised Ericsson and Kirk's (2001) adaption of Ericsson and Simon's (1993, pp. 375-379) original protocol. The training session included instruction and practice on thinking aloud and giving immediate retrospective verbal reports by solving a series of both generic- and sport-specific tasks (for an extended review, see Eccles, 2012). On average, the verbal report training protocol lasted approximately 30 min.

At the end of the instruction phase, participants were presented with a total of four practice trials to ensure familiarisation with the experimental setting and the protocol procedure. Retrospective verbal reports were collected directly after every trial. After providing verbal reports, the participants were required to confirm 'What the player in possession was going to do?' and 'What decision the participant themselves made or were about to make at the moment of video occlusion?' Participants completed 20 test trials in a quiet room. Each individual training and test session was completed in approximately 60 min. The order of presentation of the clips was kept consistent across all participants.

Outcome Data Analysis

Two outcome measures of performance were obtained. First, anticipation accuracy was defined as whether or not the participant correctly selected the next action of the player in possession of the ball at the moment of video occlusion (e.g., passed to a teammate and which teammate, shot at goal, or continued dribbling the ball). Second, the three UEFA qualified soccer coaches independently selected the most appropriate decision for a participant to execute in response to the on-screen situation at the time of video occlusion on each trial. For example, if the player in possession on screen was about to shoot at goal at the moment of video occlusion, then the most appropriate strategic decision for the participant was to move to block the shot. The inter-observer agreement between coach selections was 91.7%. Decision-making accuracy was defined as whether or not the participant decided on the action selected by the coaches as most appropriate for that trial. For the decision-making dependent measure, the correspondence between the participants' action selection (as determined through verbal confirmation by participants of their decision on each trial) and action execution (as determined through video observation of participants on each trial) was 100%.

Both anticipation and decision making accuracy were calculated as the mean number of trials (in %) in which the participant made the correct response. The between-group differences on each of the two outcome measures were analysed separately using independent *t* tests.

Verbal Report Data Analysis

On completion of the experiment, an individual unfamiliar with the experiment transcribed each participant's statements verbatim. In order to ensure the transcriptions were accurate, another individual with no knowledge of the experiment checked the statements. The three most discriminating trials between skilled and less skilled participants based on group mean scores from the anticipation and decision making measures were chosen for verbal analysis (cf. McRobert, Williams, Ward, & Eccles, 2009). These trials were subsequently coded for each participant using the protocol analysis technique described by Ericsson and Simon (1993). The transcriptions of retrospective verbal reports were divided up into segments using natural speech and other syntactical markers.

Verbal reports were classified according to a structure originally adapted from Ericsson and Simon (1993) and further developed by Ward, Williams, and Ericsson (2003). The four major statement categories included: (a) *monitoring statements* were those recalling current actions or descriptions of current events; (b) *evaluations* were statements making some form of comparison, assessment, or appraisal of events that are situation, task, or context relevant; (c) *predictions* referred to statements anticipating or highlighting future or potential future events; and (d) *planning statements* were those referring to a decision(s) on a course of action in order to anticipate an outcome or potential outcome event.

The data reliability was established using the intra-observer (94.5%) and inter-observer (93.3%) agreement methods. To provide these figures, just over 20.0% of the data were re-analysed (Thomas, Nelson, & Silverman, 2005). Statistical analysis was conducted using a factorial two-way ANOVA with Group (movement, non-movement) as the between-participant factor and Type of Verbal Statement (monitoring, evaluation, prediction, planning) as within-participant factors. The effect sizes were calculated using partial eta squared (η_p^2) values and Cohen's *d* as appropriate. Any significant main effect was followed up using Bonferroni-corrected pairwise comparisons. The alpha level was set at $p < .05$.

Results and Discussion

Outcome Data

There was no significant difference in performance on the anticipation response accuracy between the movement (M = 60.0%, SD = 12.9) and non-movement group (M = 59.5%, SD = 7.3), $t(14.02) = 0.11, p = .92, d = 0.05$. For the decision making response accuracy scores there was no significant difference between the two groups, although this difference was close to reaching significance, $t(18) = 1.79, p = .090, d = 0.80$. The mean percentage of correct decision making responses for the movement group (M = 79.5%, SD = 8.0) was slightly higher than that for the non-movement group (M = 73.0%, SD = 8.2). These findings contrast with previous research in which experimental environments of enlarged functional and action fidelity elicited greater performance responses (e.g., Mann et al., 2010). However, results from decision making performance show that if the participants' sample size was to be increased in a future study, this difference in response accuracy between movement and non-movement groups could eventually lead to reach statistical significance.

Verbal Report Data

There was a significant main effect for group, $F(1, 18) = 280.33, p < .001, \eta_p^2 = .94$. The movement group ($M = 7.37$ statements, $SD = 2.05$) generated significantly more verbal statements of cognitive processes when compared with the non-movement group ($M = 4.37$ statements, $SD = 0.85$). A significant main effect for type of verbal statement was observed, $F(3, 54) = 61.40, p < .001, \eta_p^2 = .77$. Bonferroni-corrected pairwise comparisons demonstrated that participants verbalised significantly more monitoring statements ($M = 3.27$ statements, $SD = 1.12$) compared with all other statement types. A higher number of predictive statements ($M = 1.15$ statements, $SD = 0.44$) were verbalised compared with evaluation statements ($M = 0.60$ statements, $SD = 0.71$). No differences were found between planning statements ($M = 0.85$ statements, $SD = 0.81$) and evaluation or predictive statements. These data are presented in Table 2.1.

The Group x Type of Verbal Statement interaction was not significant, $F(3, 54) = 0.58, p = .63, \eta_p^2 = .03$. However, because of the significant between-group difference in which the movement group made more statements compared to the non-movement group the frequency scores for each category were normalised into percentage data. The non-movement participants made a greater proportion of monitoring statements compared to any other type of statement ($M = 67.4\%$, $SD = 13.0$ vs. $M = 32.6\%$, $SD = 13.0$). In contrast, the movement group made a lower proportion of monitoring statements compared to any other statement type ($M = 48.6\%$, $SD = 10.1$ vs. $M = 51.4\%$, $SD = 10.1$), indicating they engaged in a greater amount of higher-order cognitive processing (i.e., evaluations, predictions, and planning).

Table 2.1

Mean (SD) Frequency Scores per Trial for Type of Verbal Statement Across Groups

	Group	
Type of verbal statement	Movement	Non-movement
Total statements	7.37 (2.05)	4.37 (0.85)
Monitoring	3.60 (1.30)	2.93 (0.83)
Evaluation	0.93 (0.77)	0.27 (0.47)
Prediction	1.43 (0.32)	0.87 (0.36)
Planning	1.40 (0.70)	0.30 (0.48)

The follow-up analysis on percentage data showed that participants in the movement task condition generated a higher percentage of evaluation, prediction, and action planning statements than participants in the non-movement task. These data suggest that participants in the movement group activate a greater number of higher-order, domain-specific processing strategies to solve the task compared with the non-movement group. These results are in agreement to those presented in previous work examining gaze behaviours under more and/or less realistic and representative experimental conditions in soccer contexts (e.g., Dicks et al., 2010a; Mann et al., 2009). The possibility of moving and interacting with the scenario in the movement condition, as opposed to the non-movement task (as per many of previous anticipation studies using similar video-based simulation tasks in open-play soccer contexts), may have amplified task engagement promoting a higher number and degree of reasoning about potential future events and planning of decisional responses to possible outcome situations.

Experiment 2

The aim in this experiment was to establish construct validity for the perceptual-cognitive representative task employed in Experiment 1. Construct validity is the degree to which scores from a test measure a hypothetical construct, such as anticipation and decision making (Thomas et al., 2005). In order to certify that the simulation task applied in this study effectively measures and captures perceptual-cognitive skills within the domain in question, it is important to establish construct validity for the task to be employed in future studies of this research programme. For this purpose, the validation procedure of the simulation test was performed using both anticipation and decision making response accuracy scores across two distinct skill groups of skilled and less skilled participants. It was expected that skilled soccer players would demonstrate superior and more accurate anticipation (e.g., North et al., 2009; Ward & Williams, 2003) and decision making (e.g., Helsen & Starkes, 1999; Vaeyens et al., 2007b) when compared with the less skilled counterparts. Such results would provide construct validity for the representative laboratory task simulation.

Methods

Participants

A total of 20 (10 skilled and 10 less skilled) adult male soccer players participated in this experiment. None of these participants took part in Experiment 1. Skilled participants (*M* age = 22.1 years, *SD* = 3.2) were semi-professional players with an average of 13.7 years (*SD* = 2.6) playing experience, during which they had trained/played for a mean of 9.3 hr (*SD* = 2.2) per week and participated in an average total of 655 (*SD* = 120) competitive matches. Less skilled participants (*M* age = 22.9 years, *SD* = 2.4) had not participated in the sport above amateur or recreational level. They had played soccer irregularly for an average of 10.5 years (*SD* = 3.5), including participation in a mean total of 103 matches (*SD* = 81) and averaging 1.5 hr (*SD* = 1.2) per week in practice. Informed consent was provided prior to participation and the research procedures were conducted according to the ethical guidelines of the lead institution.

Test Film

The test film was the same as in Experiment 1.

Apparatus and Procedure

The apparatus and procedure were the same as in Experiment 1, except that no recording of verbal reports were conducted in this experiment. Both groups of participants were free to move and interact with the action sequence as per the movement group in the previous experiment (i.e., more realistic representative task). Additionally, three different starting positions were marked on the floor in this experiment (i.e., one central to the screen, one 40 cm to the right of centre, and one 40 cm to the left of centre). Starting positions ensured that the participant began each particular clip accurately positioned relative to the on-screen action (as determined by the panel of coaches) (see Figure 2.1). At the end of each clip, participants were required only to verbally confirm their anticipation and decision making responses. Participants were tested individually and each training and test session was completed in around 30 min.

Outcome Data Analysis

The measures of performance were the same as in Experiment 1.

Results and Discussion

Outcome Data

The mean data for outcome scores are presented in Figure 2.2. As predicted, skilled participants were more accurate compared with less skilled participants at anticipating the actions of their opponents ($M = 65.5\%$, $SD = 8.3$ vs. $M = 35.0\%$, $SD = 6.2$), $t(18) = 9.28$, $p < .001$, $d = 4.15$. Skilled participants were also more accurate than their less skilled peers in deciding on an appropriate action ($M = 77.5\%$, $SD = 8.2$ vs. $M = 48.0\%$, $SD = 10.6$), $t(18) = 6.95$, $p < .001$, $d = 3.11$. Such differences in anticipation and decision making accuracy across skill groups are consistent with those found in previous studies using film-based simulations in soccer (e.g., North et al., 2009; Ward & Williams, 2003; Helsen & Starkes, 1999; Vaeyens et al., 2007b). In the current experiment, however, a significantly higher difference in performance was reported across skill groups when compared with previous studies. For example, in North et al. (2009) study, there was no more than 10% difference in anticipation performance between skilled and less skilled participants, whereas in the present experiment this difference is around 30%. This variation may be, in part, due to the more realistic and representative environmental stimuli presented during this experimental task (e.g., continuous functional movement responses to action). The overall findings of this experiment display a high degree of construct validity of the task design, providing a valid measure of anticipation and decision making and the processing mechanisms underpinning these superior component skills (see Ericsson & Williams, 2007).

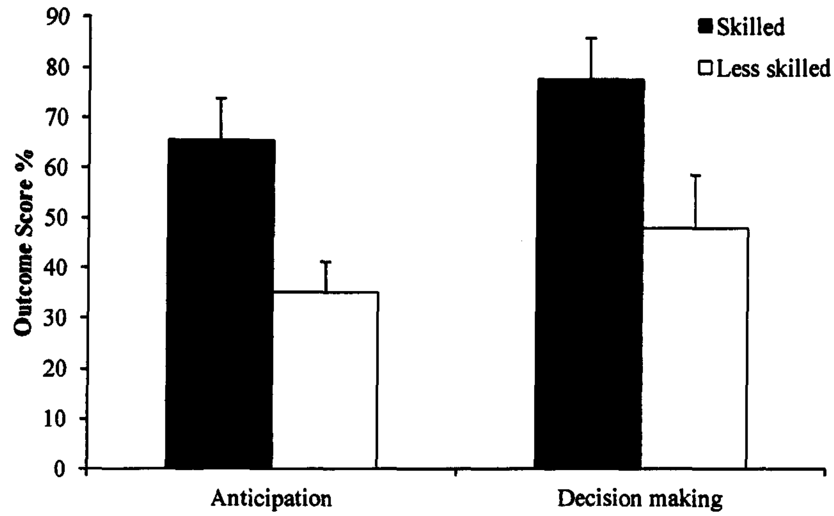


Figure 2.2. Mean (SD) outcome scores for anticipation and decision making accuracy across groups.

General Discussion

In recent years the criticisms and concerns about the ecological representativeness and fidelity of studies in the area of sports expertise (e.g., Davids, 2008; Dicks et al., 2009; Williams & Ericsson, 2005; Ward, Williams, & Hancock, 2006) have led researchers to become more aware of the need to develop representative experimental tasks for testing and training the processes and component skills underpinning superior performance. With this in mind, the aim of the first experiment was to design and identify a representative task of dynamic open-play 11 versus 11 soccer situations that effectively captured anticipation and decision making ability within this particular sporting domain. The cognitive thought processing strategies (i.e., verbal reports of thinking) of skilled adult soccer players were compared under two distinct experimental task constraints (i.e., non-movement and movement condition). Based on previous research examining performance accuracy and perceptual processing behaviours of participants across more and less realistic simulations of the performance context (e.g., Dicks et al., 2010a; Mann et al., 2010), it was hypothesised that differences in experimental fidelity would lead verbal reports of underlying cognitive processes to differ between the two task manipulations. In Experiment 2, an attempt was made to examine the construct validity of the representative task. The movement simulation task condition from Experiment 1 was, therefore, replicated across a new sample of different skill-based groups. It was expected that skilled participants would demonstrate superior anticipation and decision making compared with their less skilled counterparts.

As predicted, Experiment 1 provided clear evidence that the cognitive processes differ across the high-fidelity movement condition and low-fidelity 'sitting' condition. Participants in the movement task group generated significantly more verbal reports of cognitive processes, including a higher proportion of evaluation, prediction, and planning statements when compared with the participants from the non-movement group. It is likely that more complex and sophisticated processing strategies were being employed under movement response conditions as confirmed by the greater higher-order of cognitive statements employed by the movement compared to non-movement group. This result was consistent with the findings of Dicks et al. (2010a) in which different and more pertinent visual search patterns were employed by experienced soccer goalkeepers under more representative task constraints compared with the less representative empirical task conditions.

It was predicted that participants in the movement group would have superior performance accuracy scores in comparison with their counterparts in the non-movement group. However, there was no difference in response accuracy for anticipation and decision making between the two movement groups contradicting previous work (e.g., Mann et al., 2010). Yet, for example, difference in decision making accuracy across task conditions was sufficiently close to conventional levels of significance to warrant discussion. It is expected that if a higher sample size was to be employed potential statistical significances would ultimately have been feasible. One speculation regarding the findings in this experiment is that the movement group's task condition led to perception and action processes being performed in a more integrated manner, providing a greater natural link between stimulus characteristics and response selection/execution under a more realistic environmental setting (i.e., participants required to interact and produce requisite actions in response to the continuous movement action presented on the life-size screen) (Kelso, 1995).

Experiment 2 demonstrated that skilled participants significantly outperformed their less skilled counterparts on anticipation and decision making. The evidence of a greater difference between skill groups on the accuracy responses when compared with previous studies using video-based soccer simulation tasks (e.g., North et al., 2009; Williams et al., 1994), suggests that the attempt to produce more realistic simulations is likely to enhance measurement sensitivity, increasing the possibility of identifying more meaningful and significant differences between skilled and less skilled performers. These results establish a good degree of construct validity for the movement task design and ensure that the simulation test is optimal in order to measure the processes underlying perceptual-cognitive expertise and how these are acquired in the current research programme (Williams & Ericsson, 2005).

Overall, findings highlight the importance of designing representative tasks that offer participants the opportunity for continuous decision making, perception, and action that more closely sample the environmental characteristics of many perceptual-cognitive and motor behavioural settings that define an athlete's expertise, rather than isolate each/any of these elements (i.e., perform a task in the way that closely resemble how they would typically perform in the real-world (environment) (e.g., Williams & Ericsson, 2005; de Oliveira et al., 2009). If inferences and conclusions are to be made about the specific and often complex processes that underpin and mediate truly expert performance, then scientists have to display greater attention to the functional fidelity and ecological representativeness of task designs.

A potential limitation of Experiment 1 is that the between-condition differences could be, to some extent, due to a reflection of group or individual differences. Another argument could be related to the fact that participants in the movement response condition may have put more mental effort and engagement to perform well in the task due to the increased fidelity of this task condition. In future, a rating scale for mental effort (RMSE: Zijlstra, 1993) could perhaps be applied to participants in order to measure their perceived engagement and investment on the different task conditions (e.g., Causer, Holmes, Smith, & Williams, 2011). In addition, the use of a counterbalanced, repeated-measures design with a single group could provide a clearer assurance that the data are reliable. Although difficulties related to the reduced number of trials and the potential for learning effects in this particular study were a relevant issue to consider.

In summary, in this chapter a representative task to measure the key components of anticipation and decision making in 11 versus 11 soccer scenarios was designed and validated. In Experiment 1, the representative task was used to show how the cognitive processes underpinning anticipation and decision making differed between a movement and non-movement group. Participants in the movement group verbalised a larger number of cognitive statements with a higher proportion related to the assessment and prediction of future options and the planning and selection of an appropriate action response when compared with the participants for the non-movement task condition. In Experiment 2, the construct validity of the task was shown when skilled participants were more accurate at anticipation and decision making in comparison with their less skilled counterparts. Findings suggest a higher degree of fidelity and ecological representativeness of the movement response experimental paradigm, highlighting the need for research on perception and action in sport to be employed under representative designs in order to allow the generalisation of inferences and conclusions can be made most effectively.

Chapter 3

Identifying the Processes Underpinning Anticipation and Decision Making in a Dynamic Time-Constrained Soccer Task

Abstract

A representative task simulation developed in Chapter 2 was used to examine skill-based differences in the perceptual and cognitive processes underlying performance on dynamic, open-play, externally paced soccer situations. Skilled and less skilled soccer players were required to move and interact with life-size, action sequences involving 11 versus 11 soccer situations filmed from the perspective of a central defender in soccer. The ability of participants to anticipate the actions of their opponents and to make decisions about how they should respond was measured across two separate experiments. In Experiment 1, visual search behaviours were examined using an eye-movement registration system. In Experiment 2, retrospective verbal reports of thinking were gathered from a new sample of skilled and less skilled participants. Skilled participants were more accurate than less skilled participants at anticipating the actions of opponents and in deciding on an appropriate course of action. The skilled players employed a search strategy involving more fixations of shorter duration in a different sequential order and towards more disparate and informative locations in the display when compared with the less skilled counterparts. The skilled players generated a greater number of verbal report statements with a higher proportion of evaluation, prediction, and planning statements than the less skilled players, suggesting they employed more complex domain-specific memory representations to solve the task. Theoretical, methodological, and practical implications are discussed.

Keywords: *perceptual-cognitive expertise, mediating mechanisms, visual search, verbal reports*

Perceptual-cognitive skills play a crucial role in several dynamic, time-constrained domains, such as medicine (e.g., Ericsson, 2004), law enforcement (e.g., Ward, Suss, Eccles, Williams, & Harris, 2011), military combat (e.g., Williams et al., 2008), and sports (e.g., Williams & Ford, 2008). In sporting environments such as soccer, experts have been shown to have superior perceptual-cognitive skills when compared with their less expert counterparts. These skills include a superiority in recognising information from the postural orientation of opponents or teammates (e.g., Williams & Burwitz, 1993; Savelsbergh et al., 2005), faster and more accurate recognition of structured patterns within the game (e.g., North et al., 2009; Williams et al., 2006), and a superior ability to make more accurate predictions as to what other players are likely to do in any given situation (e.g., Ward & Williams, 2003). These skills enable performers to make an assessment of the current situation and select appropriate decisions under time pressure.

Traditionally, scientists have omitted to identify the mediating processes underlying the expert's superior performance at anticipation and decision making when compared to less skilled individuals. The overriding tendency has often been to identify the existing performance differences between experts and novices rather than to discover and explore the processes and mechanisms that control and mediate expert performance on a task (Ericsson & Towne, 2010). Data from process-tracing methods (e.g., eye-movement recording and verbal protocol analysis) are an important precursor to formulate and develop more detailed descriptive frameworks and/or refined theoretical models of expert performance. Across the different process-tracing measures that exist (for reviews, see Hodges, Huys, & Starkes, 2007; Williams & Ericsson, 2005), the most commonly employed by scientists within sport tasks has been the collection of eye-movement data. In general, research evidence from a number of sports has demonstrated that when compared to their novice counterparts experts tend to fixate their gaze on more informative areas of the performance setting, for varying periods of time, and using a different search strategy or sequence pattern (for a review, see Vickers, 2007). A number of different studies in the sport of soccer have been conducted to explore the visual search behaviours of performers of different skill levels (e.g., Helsen & Starkes, 1999; North et al., 2009; Vaeyens et al., 2007a, b; Williams et al., 1994). For example, Williams et al. (1994) investigated visual search strategy and anticipation of defender participants in 11 versus 11 open-play soccer situations presented in film format that were recorded from an elevated position behind the goal. The results indicated that experienced players who were superior at anticipation fixated for shorter durations on more informative locations in the visual display, such as the positions and movements of other players, in comparison with their less experienced peers.

In another study involving similar 11 versus 11 soccer sequences, North et al. (2009) showed that when asked to anticipate the ball outcome destination, skilled participants fixated more different locations of the display than less skilled participants. Other researchers have attempted to examine the search patterns employed during tactical decision making in soccer. Helsen and Starkes (1999) presented participants with video simulations of offensive set-plays and open-play situations containing a restricted number of players. They were required to determine, as quickly and accurately as possible, whether the most appropriate decision was to shoot at goal, pass to a specific and free teammate, or dribble around an opponent on the screen. The expert offensive players revealed fewer fixations and fixated more on the positioning of the free back or sweeper and potential areas of free space, while non-experts fixated on potentially less informative cues such as ball, the goal, and some other attackers. Vaeyens et al. (2007a, b) also measured visual search behaviours and decision making skill across different microstates of offensive play in soccer. They demonstrated that skilled players spent more time fixating the player in possession of the ball and also shifted their gaze away from the 'player in possession' more frequently compared with less skilled players. Such differences in visual search behaviours are thought to underpin the superior anticipation and decision making skills of expert performers when compared with those less experts.

Although several researchers have examined the visual search behaviours employed during sporting performance, none have examined it when players are both anticipating and making positional decisions. By examining anticipation or decision making in isolation, it may potentially bias participants to process information in a manner that differs to how they normally would in actual performance. Moreover, relatively few have sought to better understand how experts process the visual information when making strategic and tactical decisions (for exceptions, see McPherson, 2000, 2008). This latter issue may be addressed by collecting verbal reports as a measure of the thought processes used during task performance (Ericsson & Simon, 1993). Verbal report protocols provide a comprehensive explanation into the cognitive processes mediating perception, decision making, and action, as well as how information is stored, retrieved, and processed. When engaged in domain-specific tasks involving anticipation and/or decision making, skilled performers have generally provided more detailed verbal reports of thinking in comparison with less skilled individuals (e.g., North et al., 2011; McRobert, Ward, Eccles, & Williams, 2011; Ward et al., 2003).

For example, Ward and colleagues (2003) used verbal reports to identify the cognitive processes that mediate how players anticipate and evaluate/prioritise the available options or potential next best move of an opposition player in possession of the ball in soccer. Verbal protocols suggested that elite players immediately recognised the key options available and used an efficient search-based process to evaluate and confirm initial perceptions. In contrast, sub-elite players predominantly relied in a more exhaustive and less effective monitoring/search process prior to eliciting the (correct) response. Such findings have been interpreted as support for long-term working memory theory (LTWM; for a review, see Ericsson & Kintsch, 1995). The LTWM theory holds that expert performers develop domain-specific memory structures that allow rapid and reliable encoding and retrieval of information in long-term memory, thus circumventing the capacity limitations of short-term memory and the difficulties of retrieval from long-term memory.

In the experiments reported in this chapter, an attempt is made to examine the underlying processes of anticipation and decision making using a soccer representative task simulation under controlled and reproducible conditions in the laboratory (see Chapter 2). The simulation includes video filmed from a first-person perspective of an 11 versus 11 soccer match, a movement-based response that is similar to the real-world setting, and measures of both anticipation *and* decision making. Eye-movement recording (Experiment 1) and verbal reports of thinking (Experiment 2) are employed to provide a more detailed and comprehensive analysis of the processes underlying perceptual and cognitive expertise in a dynamic, time-constrained soccer task.

Experiment 1

The aim of this experiment was to examine the visual search behaviours employed by skilled and less skilled participants when attempting to anticipate and make decisions during 11 versus 11 dynamic situations in soccer. Previous literature suggests that successful anticipation and decision making in soccer requires that players direct visual attention to the most informative locations in the visual display (e.g., movements and positions of other players) at the appropriate time, in order to extract critical information to guide action selection and execution (Williams et al., 2004). It was predicted that skilled soccer players would demonstrate superior anticipation and decision making compared with less skilled players, which would be underpinned by skill-based differences in visual search behaviours. Specifically, it was hypothesised that skilled participants would employ more fixations of shorter duration and would fixate on more informative locations in the visual display (e.g., opponents/teammates) when compared with their less skilled counterparts (e.g., North et al., 2009; Williams et al., 1994). For skilled participants, this may include fixations alternating more frequently between the player in possession of the ball/ball itself and other areas of the display in comparison with less skilled participants (as per Vaeyens et al., 2007a, b).

Methods

Participants

A total of 20 (10 skilled and 10 less skilled) adult male soccer players participated. Skilled participants (*M* age = 23.6 years, *SD* = 3.8) were professional (*n* = 5) and semi-professional (*n* = 5) players. They had an average of 14.8 years (*SD* = 3.3) playing experience, during which they had trained/played for a mean of 10.2 hr (*SD* = 2.5) per week, including participation in an average total of 710 (*SD* = 144) competitive matches. Less skilled players (*M* age = 24.3 years, *SD* = 2.4) had not participated in the sport above amateur or recreational level. They had played soccer irregularly for an average of 11.3 years (*SD* = 4.1), participating in a mean total of 85 (*SD* = 67) competitive matches and averaging 1.2 hr (*SD* = 1.1) per week in practice. Participants provided informed consent and were free to withdraw from testing at any stage. All procedures were conducted according to the ethical guidelines of the lead institution.

Test Film

Participants were presented with life-size video sequences of dynamic, 11 versus 11 soccer situations from the first-person perspective of a central defender (for a detail description on the creation of the test film, see Chapter 2, pp. 29-30). The test film consisted of four practice and 20 test trials. At the start of each clip, a red dot appeared on a black background to indicate where the ball would be located at the start of the film sequence. Such a procedure enabled participants to be aware of where the ball was from the outset of the clip, thus stopping them conducting a search for it during the opening frames of the video clip as per previous studies (e.g., North & Williams, 2008). This procedure was followed by a photograph of the first frame of the clip that was visible for 1.5 s before the video commenced. A panel of three UEFA qualified soccer coaches unanimously deemed this orientation essential because players in a soccer match are in general aware of the position of the ball, and to some extent where their teammates/opponents are, during play. The video clips each lasted approximately 5 s, with each one being occluded 120 ms prior to the player in possession of the ball making a key attacking pass, shooting at goal, or maintaining possession of the ball by dribbling forward. Each video clip ended with a white screen in order to prevent the participants from receiving any information from the last frame when the clips were occluded.

Apparatus

The film clips were back projected, using a 3LCD video projector (Hitachi ED-A101, Yokohama, Japan) with XGA resolution onto a 2.7 m (h) x 3.6 m (w) large projection screen (Draper Cinefold, Spiceland, IN, USA). Participants stood 2.5m away from the screen so that the film image subtended a visual angle of approximately 35° in the horizontal and 28° in the vertical direction. Three different starting positions were marked on the floor (i.e., one to the right, one to the left, and one central to the screen) to ensure that the participant began each particular clip accurately positioned relative to the on-screen action (as determined by the panel of coaches). Participants were free to move and interact with the action sequence as they would normally do when playing in a real soccer match. Participants' movement responses were monitored using a digital video camera (Canon LEGRIA FS200, Tokyo, Japan) positioned 3m behind the participant and linked to a TV monitor screen (Philips 15PF5120, Eindhoven, Netherlands) placed on the experimenter's desk.

A mobile eye-tracking system (Applied Science Laboratories, Bedford, MA, USA) was used to collect participants' visual search data. The Mobile Eye is a video-based monocular system that measures eye point-of-gaze with respect to a head-mounted scene camera. The system works by linking together information from the corneal reflection and pupil, obtained via an infrared light source and a camera focused on the eye, with the scene image provided by the head-mounted camera optics. The result is a computed point-of-gaze superimposed as a cursor onto the scene camera image. The data were analysed frame-by-frame using SportsCode

Gamebreaker V8 software (Sportstec, Sydney, Australia). The accuracy of the system was ± 1° visual angle, with a precision of 1° in both horizontal and vertical direction.

Procedure

Prior to commencing the experimental task, the test procedure was explained and the eye-movement system fitted onto the participant's head. The system was calibrated using a reference of 6-9 nonlinear points on the scene image so that the recorded indication of fixation position corresponded to each participant's point-of-gaze. Periodic calibration checks were conducted before and during presentation of the test film and minor adjustments made as necessary.

Following the initial calibration, participants received four practice trials to familiarise themselves with the experimental procedure. At the end of each clip, participants were required to confirm 'What the player in possession was going to do?' and 'What decision the participant themselves made or were about to make at the moment of video occlusion?' Participants completed 20 test trials and each individual test session was concluded in approximately 45 min. The order of presentation of the clips was kept consistent across all participants.

Outcome Data Analysis

Two outcome measures of performance were obtained. First, anticipation accuracy was defined as whether or not the participant correctly selected the next action of the player in possession of the ball at the moment of video occlusion (e.g., passed to a teammate and which teammate, shot at goal, or continued dribbling the ball). Second, the three UEFA qualified soccer coaches independently selected the most appropriate decision for a participant to execute in response to the on-screen situation at the time of video occlusion on each trial. For example, if the player in possession on screen was about to shoot at goal at the moment of video occlusion, then the most appropriate strategic decision for the participant was to move to block the shot. The inter-observer agreement between coach selections was 91.7%. Decision making accuracy was defined as whether or not the participant decided on the action selected by the coaches as most appropriate for that trial. For the decision making dependent measure, the correspondence between the participants' action selection (as determined through verbal confirmation by participants of their decision on each trial) and action execution (as determined through video observation of participants on each trial) was 100%.

Both anticipation and decision making accuracy were calculated as the mean number of trials (in %) in which the participant made the correct response. The between-group differences on each of the two outcome measures were analysed separately using independent *t* tests.

Visual Search Data Analysis

The three most discriminating trials between skilled and less skilled participants based on group mean scores from the measures of anticipation and decision making accuracy were chosen for visual search analysis (cf. McRobert et al., 2009). Three measures of visual search behaviour were analysed.

Search rate. Three measures of search rate were examined. These were the mean number of fixations per trial, the mean number of fixation locations per trial, and mean fixation duration (in milliseconds). A fixation was defined as a condition in which the eye remained stationary within 1.5° of movement tolerance for a period equal to, or in excess of, 120 ms or 3 video frames (Williams & Davids, 1998). The between-group differences across each of these three measures of search rate were analysed separately using independent *t* tests.

Percentage viewing time. This measure was the percentage of total viewing time spent fixating various areas of the display. The display was initially divided into six fixation locations: player in possession of the ball; ball (i.e., ball flight); opponent player; teammate player; space (i.e., areas of free space on the soccer pitch in which no player is located); and an unclassified category for fixations that did not match with the aforementioned locations. The unclassified category was eventually excluded because none of participants' fixations fell outside any of the other five locations. Percentage viewing time data were analysed using a factorial two-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Fixation Location (player in possession of the ball, ball, opponent, teammate, space) as within-participant factors. Greenhouse-Geisser procedures were used to correct for violations of the sphericity assumption. Partial eta squared (η_p^2) values and Cohen's *d* effect size measures were calculated as appropriate. Any significant main and interaction effects were followed up using Bonferroni-corrected pairwise comparisons and Tukey's HSD post hoc tests, respectively.

Fixation order. Fixation order referred to the search sequence or pattern used by the participants. The average frequency per trial that participants alternated their gaze between the player in possession of the ball/ball itself, some other area of the display, and then back to the player in possession of the ball/ball itself was employed as the dependent variable (cf. Williams et al., 1994; Williams & Davids, 1998). Fixation order data were analysed using an independent *t* test.

The alpha level required for significance for all tests was set at $p < .05$. Visual search data reliability was established using the intra-observer (94.6%) and inter-observer (91.8%) agreement methods. Altogether, just over 20.0% of the data were re-analysed to provide the agreement figures using the procedures recommended by Thomas et al. (2005).

Results and Discussion

Outcome Data

As predicted, skilled players were more accurate than less skilled counterparts at anticipating the actions of opponents (M = 70.0%, SD = 6.7 vs. M = 36.5%, SD = 6.7), $t(18) = 11.22$, $p < .001$, $d = 4.90$. Skilled players were also more accurate compared with less skilled players in deciding on an appropriate course of action (M = 81.0%, SD = 5.7 vs. M = 48.0%, SD = 10.3), $t(18) = 8.86$, $p < .001$, $d = 3.84$. The results support previous research where film-based simulations have been used to independently measure anticipation (Ward & Williams, 2003; Williams & Davids, 1998) and decision making (Helsen & Starkes, 1999; Vaeyens et al., 2007b) in soccer. As a result of a more extensive engagement within the domain, skilled players have acquired a superior ability to anticipate and make decisions under time pressure compared with less skilled players (Williams & Ford, 2008).

Visual Search Data

Search rate. The results are presented in Table 3.1. There were significant skill-based differences in the mean fixation duration, $t(11.19) = -8.81$, $p < .001$, $d = -3.95$, mean number of fixations, $t(18) = 12.30$, $p < .001$, $d = 5.49$, and the mean number of fixation locations per trial, $t(18) = 10.41$, $p < .001$, $d = 4.63$. The visual search strategy of skilled participants involved more fixations of shorter duration and on significantly more locations in the visual display compared with the less skilled participants. Differences in visual search rate were similar to those presented in previous work using eye-movement recording and 11 versus 11 film-based simulations in soccer (e.g., North et al., 2009; Williams et al., 1994). However, the present study reports significantly more fixations compared with previous reports. For example, in the North et al. (2009) paper, the skilled participants made 1.4 fixations per second, whereas in the current experiment skilled participants made 2.6 fixations per second.

Table 3.1

Mean (SD) Number of Fixations, Number of Fixation Locations, and Fixation Duration per Trial Across Groups

	Group	
Search rate	Skilled	Less skilled
No. of fixations	12.93 (1.20)	6.77 (1.04)
No. of fixation locations	6.93 (0.97)	3.40 (0.47)
Fixation duration (ms)	369 (49)	780 (139)

Percentage viewing time. The mean data for percentage viewing time are presented in Figure 3.1. There was a significant main effect for fixation location, $F(2.07, 37.23) = 87.64$, $p < .001$, $\eta_p^2 = .83$. Bonferroni-corrected pairwise comparisons demonstrated that participants spent significantly more time fixating the player in possession of the ball ($M = 50.6\%$, $SD = 14.6$) compared with any other fixation location. Fixations on the ball ($M = 20.3\%$, $SD = 12.6$) and opponents ($M = 15.0\%$, $SD = 11.8$) were significantly greater than those on areas of free space ($M = 7.3\%$, $SD = 7.6$) and teammates ($M = 6.9\%$, $SD = 6.9$), whereas no differences were evident between the latter two categories.

A significant Group x Fixation Location interaction was observed, $F(2.07, 37.23) = 21.57, p < .001, \eta_p^2 = .55$. Post hoc Tukey's HSD tests revealed that less skilled participants spent significantly more time fixating the player in possession of the ball (M = 59.1%, SD = 10.1) and the ball's movement (M = 30.8%, SD = 7.9) compared with the skilled participants (M = 42.1%, SD = 13.7 and M = 9.7%, SD = 5.0, respectively). This finding contradicts that reported by Vaeyens et al. (2007a, b), who found that skilled players fixated the player in possession more when compared with less skilled players. In contrast, skilled participants spent significantly more time fixating on the opponents (M = 24.3%, SD = 9.6) and areas of free space (M = 12.7%, SD = 7.2) compared with their less skilled counterparts (M = 5.6%, SD = 2.8 and M = 1.8%, SD = 1.9, respectively).

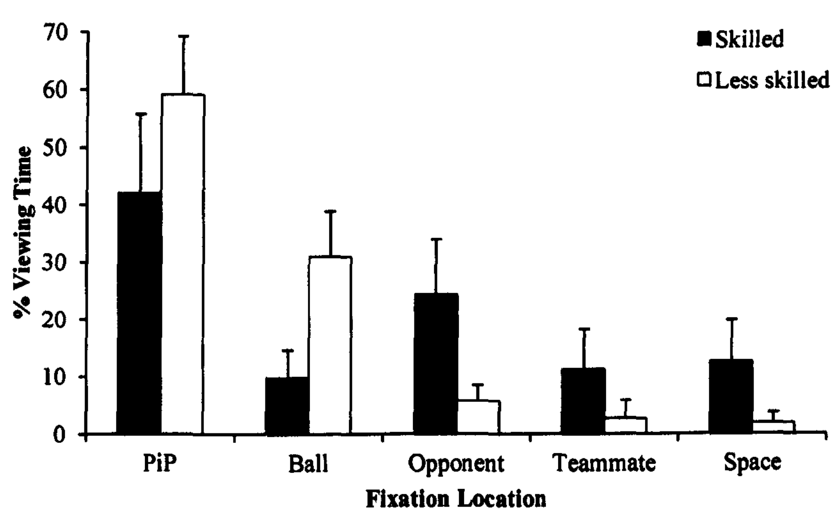


Figure 3.1. Mean (SD) percentage of time spent viewing each fixation location across groups. (*PiP* player in possession of the ball).

Fixation order. Skilled participants (M = 1.67 fixation switches, SD = 0.54) alternated their gaze more frequently between the player in possession of the ball/ball itself and any other area of the scene when compared with less skilled participants (M = 0.40 fixation switches, SD = 0.41), $t(18) = 5.89$, $p < .001$, $d = 2.65$. This skill-based difference in fixation order was also reported by Vaeyens et al. (2007a, b). However, a higher search order was reported for skilled participants in this experiment when compared with prior work examining the same scanning pattern (e.g., Vaeyens et al., 2007a; Williams et al., 1994). This search pattern is regarded as being advantageous, particularly during highly dynamic open-play situations, since it enhances the player's awareness of the positions and movements of teammates and opponents, as well as areas of free space that may be exploited or exposed (Williams & Davids 1998).

Findings from this experiment highlighted a number of systematic differences in visual search behaviour across the two skill groups. Such differences in visual search behaviours were to some degree similar to those presented in previous work. Yet, some differences were found in this study for some of the visual search data (e.g., higher number of fixations and search order) in comparison with previous similar studies. The reason for these differences may be related to the use, in this study, of more realistic environmental stimuli involving functional movement responses to 11 versus 11 soccer action sequences filmed from a first-person perspective and presented on a life-size screen (e.g., Dicks et al, 2010a). The overall findings of this experiment lead us to suggest that differences in visual search behaviours may, in part, explain the superior anticipation and decision making performance of skilled soccer players.

Experiment 2

The aim in the second experiment was to examine the thought processes that underpin anticipation and decision making during the representative task used in Experiment 1. The collection of verbal reports of thinking in this experiment is expected to provide valuable insight into the nature of thought processes used during actual performance (Ericsson & Simon, 1993). For example, because of their superior LTWM (Ericsson & Kintsch, 1995) skilled players are generally expected to engage in more situational assessment, predictions, and decisional planning during time-constrained sporting tasks in comparison with less skilled players (McRobert et al., 2011; North et al., 2011; Ward et al., 2003). Based on previous findings, it was hypothesised that skilled participants' more advanced memory representations of the current game situation would be evidenced by a larger number of verbal report statements, including more statements categorised as evaluation, prediction, and planning compared with their less skilled counterparts.

Methods

Participants

A total of 20 (10 skilled and 10 less skilled) adult male soccer players were recruited. None of these participants took part in Experiment 1, although these participants were of the same skill level compared with the previous sample. Skilled participants (*M* age = 23.8 years, *SD* = 4.8) were professional (*n* = 6) and semi-professional (*n* = 4) players. They had been playing soccer for an average of 14.9 years (*SD* = 4.3), during which they had trained/played for a mean of 10.4 hr (*SD* = 2.8) per week, including participation in an average total of 735 (*SD* = 151) competitive matches. Less skilled players (*M* age = 24.7 years, *SD* = 3.8) had participated only at an amateur or recreational level. They had played soccer infrequently for an average of 11.5 years (*SD* = 3.1), participating in a mean total of 70 (*SD* = 65) competitive matches and averaging 1.0 hr (*SD* = 1.1) per week in practice. Participants provided informed consent and were free to withdraw from testing at any stage. All procedures were conducted according to the ethical guidelines of the lead institution.

Test Film

The test film was the same as in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1, except that no eye-tracking system was used to record point-of-gaze. A lapel wireless microphone set (Sennheiser EW-100G2, Wedemark, Germany), including a telemetry radio transmitter fixed to the participant and a telemetry radio receiver connected to the digital video camera, was employed so as to collect verbal reports.

Procedure

Prior to testing, participants received instruction and training on how to think aloud and provide retrospective verbal reports. These instructions comprised Ericsson and Kirk's (2001) adaption of Ericsson and Simon's (1993, pp. 375-379) original protocol. The training session integrated both instruction and practice on thinking aloud and giving immediate retrospective verbal reports by solving a series of generic- and sport-specific tasks (for an extended review, see Eccles, 2012). On average, the verbal report training protocol lasted approximately 30 min.

At the end of the instruction phase, participants were presented with four practice trials to ensure familiarisation with the experimental setting and the protocol procedure. Retrospective verbal reports were collected directly after every trial.

Participants were tested individually in a quiet room, and each test session was completed in around 60 min.

Outcome Data Analysis

The measures of performance were the same as in Experiment 1.

Verbal Report Data Analysis

On completion of the experiment, an individual unfamiliar with the experiment transcribed each participant's statements verbatim. In order to ensure the transcriptions were accurate, another individual with no knowledge of the experiment checked the statements. The three most discriminating trials between skilled and less skilled participants based on group mean scores from the anticipation and decision making measures were chosen for verbal analysis (cf. McRobert et al., 2009). These trials were subsequently coded for each participant using the protocol analysis technique described by Ericsson and Simon (1993). The transcriptions of retrospective verbal reports were divided up into segments using natural speech and other syntactical markers.

Verbal reports were classified according to a structure originally adapted from Ericsson and Simon (1993) and further developed by Ward et al. (2003). The four major statement categories included: (a) *monitoring statements* were those recalling current actions or descriptions of current events; (b) *evaluations* were statements making some form of comparison, assessment, or appraisal of events that are situation, task, or context relevant; (c) *predictions* referred to statements anticipating or highlighting future or potential future events; and (d) *planning statements* were those referring to a decision(s) on a course of action in order to anticipate an outcome or potential outcome event.

The data reliability was established using the intra-observer (92.2%) and inter-observer (88.0%) agreement methods as in Experiment 1. To provide these figures, just over 20.0% of the data were re-analysed (Thomas et al., 2005). Statistical analysis was conducted using a factorial two-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Type of Verbal Statement (monitoring, evaluation, prediction, planning) as within-participant factors. Significant main and interaction effects were followed up as in Experiment 1.

Results and Discussion

Outcome Data

Skilled participants were more accurate compared with less skilled participants at anticipating the actions of their opponents (M = 68.0%, SD = 8.0 vs. M = 35.0%, SD = 9.9), $t(18) = 8.24, p < .001, d = 3.66$. Skilled participants were also more accurate than their less skilled counterparts in deciding on an appropriate course of action (M = 81.5%, SD = 8.8 vs. M = 52.0%, SD = 7.2), $t(18) = 8.14, p < .001, d = 3.65$. These skill-based differences are the same as those found in Experiment 1, as well as in previous research that examines these abilities in isolation (e.g., Williams & Davids, 1998; Vaeyens et al., 2007b).

Verbal Report Data

There was a significant main effect for group, $F(1, 18) = 17.40, p = .001, \eta_p^2 = .49$. Skilled participants ($M$ = 7.73 statements, SD = 1.32) generated significantly more verbal statements of cognitive processes in comparison with the less skilled group (M = 5.43 statements, SD = 1.13). These data provide support for the initial predictions made and may be indicative of skilled players having more advanced memory representations for the domain compared with their less skilled counterparts.

A significant main effect for type of verbal statement was observed, $F(3, 54) = 144.74, p < .001, \eta_p^2 = .89$. Bonferroni-corrected pairwise comparisons showed that participants generated significantly more monitoring statements (M = 3.68 statements, SD = 0.70) compared with all other statement types. A higher number of predictive statements (M = 1.22 statements, SD = 0.58) were verbalised in comparison with evaluation statements (M = 0.68 statements, SD = 0.68). No differences were found between planning statements (M = 1.00 statements, SD = 0.47) and evaluation or predictive statements. These data are presented in Table 3.2.

The Group x Type of Verbal Statement interaction was not significant, $F(3, 54) = 1.48, p = .23, \eta_p^2 = .08$. However, because the skilled participants verbalised significantly more statements in each category than the less skilled group, which may affect the outcome of interaction, the frequency scores were subsequently normalised into descriptive proportional data. Proportional data showed that less skilled participants made a higher percentage of monitoring statements in comparison with the skilled participants (M = 67.2% of statements, SD = 7.7 vs. M = 49.3% of statements, SD = 8.5). In contrast, skilled participants made a higher proportion of evaluation, prediction, and planning statements when compared with their less skilled peers (M = 50.7% of statements, SD = 8.5 vs. M = 32.8% of statements, SD = 7.7). Although there was no significant interaction between group and type of verbal statement, the follow-up analysis on percentage data showed that skilled players generated a higher proportion of evaluation, prediction, and planning statements than the less skilled group. These data suggest that skilled players may possess and activate more complex domain-specific memory representations when compared with less skilled players, allowing the current events and potential outcomes to be considered and assessed, rather than merely monitored in their present state (McPherson, 2008; Ward et al., 2003).

Table 3.2

Mean (SD) Frequency Scores per Trial for Type of Verbal Statement Across Groups

	Group	
Type of verbal statement	Skilled	Less skilled
Total statements	7.73 (1.32)	5.43 (1.13)
Monitoring	3.77 (0.79)	3.60 (0.64)
Evaluation	1.00 (0.72)	0.37 (0.48)
Prediction	1.60 (0.56)	0.84 (0.23)
Planning	1.37 (0.30)	0.63 (0.29)

General Discussion

The aim in this chapter was to examine the processes underlying superior anticipation and decision making in a dynamic time-constrained soccer task. A representative task was employed in order to simulate real-world soccer situations using life-size film images from a first-person perspective under reproducible conditions in the laboratory (see Chapter 2). Eye movements and retrospective verbal reports of thinking were collected to measure the processes underpinning superior anticipation and decision making. It was expected that skilled participants would demonstrate superior anticipation and decision making compared with their less skilled counterparts. It was further predicted that the superior performance of skilled participants would be caused by systematic differences in the underlying perceptual and cognitive processes when compared with the less skilled participants.

Skilled soccer players were more accurate in their anticipation and decision making judgments across both experiments compared with less skilled players.

Finding supports previous research that has examined these abilities in isolation (e.g., Ward & Williams, 2003; Helsen & Starkes, 1999). As predicted, the underlying processes of perception and cognition were used in a quantitatively different manner between skill groups. Skilled participants' visual search strategy involved more fixations of shorter duration, alternating their gaze more frequently between the player in possession of the ball/ball itself and other areas of the display in comparison with less skilled participants, which generally support previous research (e.g., Vaeyens et al., 2007a, b; Williams et al., 1994). The skilled participants also spent significantly more time fixating on the opponent players and areas of free space when compared with the less skilled participants. In contrast, the less skilled group spent more time fixating the player in possession of the ball and the ball's movement (as per Williams et al., 1994; also, to some degree Helsen & Starkes, 1999). This finding contradicts that reported by Vaeyens et al. (2007a, b), who found that skilled players fixated the player in possession more when compared with less skilled players. Such differences in search strategies may be, in part, due to the methodological differences in viewing perspective (e.g., first- vs. third-person perspective; Mann et al., 2009) and/or type of task constraints (e.g., attacking vs. defending situations) employed during these investigations.

Skilled players not only used a quantitatively different visual search strategy when compared with their less skilled peers but they also processed the information picked up by the visual system in a different manner. The skilled players generated a greater number of verbal reports of cognitive processes, including a higher proportion of evaluation, prediction, and planning statements in comparison with the less skilled players. In contrast, less skilled players made a greater proportion of statements recalling current actions or descriptions of current events. Findings support previous research involving time-constrained sporting tasks (e.g., North et al., 2011; Ward et al., 2003). It could be speculated that the skilled players' more advanced domain-specific memory representations enabled them to easily retrieve relevant game-related information from memory and make better judgments compared with their less skilled counterparts.

A potential limitation with the method employed in Experiment 1 is that the questions asked to participants in order to elicit their anticipation and decision making responses may have biased them to view the clips in a manner that differs to how they would do in the real-world situations. The potential implication is that the processes measured may be different to those used in the real-world. In Experiment 2, steps were taken to avoid this limitation by asking the questions after the verbal reports were provided and only asking the question if the participant had not answered them in the verbal reports (see also Chapter 2). In future, researchers should attempt to examine the underlying perceptual-cognitive processes and skills across different game-based interactive factors or constraints, including the use of more realistic conditions. They should also seek to better identify the important adaptive learning and explicit acquisition processes leading to the acquisition of these skills (e.g., Berry, Abernethy, & Côté, 2008). A more complete understanding of the interchanging processes underpinning expertise and the types of practice that lead to their development would enable those involved in talent development to design training correctly.

In summary, skilled soccer players were more accurate at anticipating the actions of opponents and making appropriate decisions than were their less skilled counterparts. The superior judgments of skilled participants were underpinned by more refined underlying processes compared with those of less skilled peers, as highlighted by skill-based differences in visual search behaviours and retrospective verbal reports of thinking. The skilled participants employed a greater number of fixations of shorter duration in a different frequency order and towards more disparate and informative locations of the display in comparison with the less skilled participants. Additionally, when compared with the less skilled counterparts, skilled participants made a higher proportion of verbal report statements that assessed the game environment and anticipated future or potential future situations, including the planning of decisional responses to possible outcome events. Potential implications of this investigation may be applied and extended across a diverse range of settings and domains, particularly where decisions have to be made under highly dynamic and temporal-constrained performance environments.

Chapter 4

Perceptual-Cognitive Skills and Their Interaction as a Function of Task and Skill Level in Soccer

Abstract

This chapter examined skill- and task-specific differences in perceptual and cognitive processes in soccer, including an initial attempt to identify how perceptual-cognitive skills interact during performance. Skilled and less skilled players interacted with life-size film sequences of 11 versus 11 soccer situations from the perspective of a central defender. Situations either started with the ball being located in the participant's offensive (i.e., *far task*) or defensive half of the pitch (i.e., *near task*). Measures of anticipation and decision making accuracy were gathered across two different experiments. In Experiment 1, visual search behaviours were examined using an eye-movement registration system. In Experiment 2, retrospective verbal reports of thinking were collected from a new sample of participants. Skilled players were more accurate at anticipation and decision making compared to less skilled players. Their advantage was underpinned by different visual search strategies and memory representations compared to less skilled players, which seemed to be governed by the changes in task constraints. Players' use of the perceptual-cognitive skills varied between near and far conditions. In the far task, skilled players in particular verbalised more thought processes that were related to the recognition of patterns of play, whereas, in the near task, they made more statements that referred to the postural orientation of opponents/teammates, followed by expectations about event outcomes (i.e., situational probabilities). These empirical findings need to be considered in future by those involved in the study and training of perceptual, cognitive, and motor skills.

Keywords: *perceptual-cognitive expertise, skills interaction, situational task constraints, mediating processes*

Over recent years, there has been a growth of interest in identifying the skills and mediating processes that reliably contribute to superior anticipation and decision making (e.g., Starkes & Ericsson, 2003; Williams & Ford, 2008). It has been reported that experts have superior perceptual-cognitive skills compared with novices, enabling them to use vision and other sensory sources to identify and recognise cues in the performance environment for integration with existing knowledge. Although there have been attempts to identify mediating processes and the specific involvement of different perceptual-cognitive skills, there have been no reported attempts to examine how these skills interact with each other to facilitate appropriate anticipation and decision making in the competitive setting (Williams & Ward, 2007).

The majority of researchers have used a reductionist approach to try and capture each perceptual-cognitive skill (e.g., postural cue usage, recognising patterns, and situational probabilities) in isolation with a stronger emphasis on experimental control rather than ecological validity or representative task design (Williams, 2009). For example, in soccer, Williams et al. (2006) presented adult soccer players with film sequences of play taken from real matches. The clips involved either structured organised attacking sequences or unstructured sequences, such as players warming-up prior match, in order to examine a singular perceptual skill termed pattern recognition. Skilled players were faster and more accurate than less skilled participants at recognising the structured and evolving sequences of play early in its development. Most researchers have focused on anticipation or postural cue usage, which has typically been examined using expert soccer goalkeepers who are attempting to anticipate the penalty taker's intentions presented on a film-based simulation test (e.g., McMorris, Copeman, Corcoran, Saunders, & Potters, 1993;

Savelsbergh et al., 2005; Williams & Burwitz, 1993). Although researchers have gained important insights into how each of the different perceptual-cognitive skills contributes to performance, it is likely that their function is not mutually exclusive and that these skills are more likely to be integrated and to interact in a reciprocal manner during performance (Williams & Ward, 2007). A better understanding of the interaction between the perceptual-cognitive skills and how this varies as a function of specific task and situational constraints is needed.

In this paper, an attempt is made to employ a novel approach to examine the potential interaction between the different perceptual-cognitive skills as a function of task constraints and skill level in soccer. A video-based simulation test is employed in addition to the manipulation of distinct situational task constraints involving different sequences of play in soccer (i.e., ball distance relative to the player/participant). The rationale for using this type of manipulation is based on a few studies that focused on trying to analyse how these underlying processes operate across a range of different task constraints within the performance setting, such as the number of players involved in the game situation. For example, Williams and colleagues (e.g., Williams et al., 1994; Williams & Davids, 1998) provided one of the first attempts to examine the visual search behaviours adopted by skilled and less skilled soccer players when viewing different defensive simulations in soccer (i.e., 11 vs. 11, 3 vs. 3, and 1 vs. 1). During the 11 versus 11 situations, skilled players fixated gaze on peripheral areas of the display, such as the offensive players' positions and movements employing more fixations of shorter duration than their less skilled peers. In contrast, less skilled players tended to fixate more frequently on the ball and the player in possession of the ball. When viewing the 3 versus 3 simulations, players typically employed fewer fixations of longer duration mainly fixating on the player in possession of the ball or the ball itself with relatively few fixations to disparate aspects of the display. In response to 1 versus 1 situations, skilled players employ a greater frequency of fixations between the hip and ball foot region compared with less skilled players, who fixate largely on the ball.

In similar vein, Vaeyens et al. (2007a, b) analysed the visual search strategy behaviours employed by youth players across the different microstates of offensive play situations in soccer (i.e., 2 vs. 1, 3 vs.1, 3 vs. 2, 4 vs. 3, and 5 vs. 3 simulations). When players were presented with the 2 versus 1 and 3 versus 1 offensive simulations, they employed a smaller number of fixations of longer duration mostly towards the ball or the player in possession of the ball. In contrast, a higher number of fixations of shorter duration and to more distinct information sources were employed during the 3 versus 2, 4 versus 3, and 5 versus 3 situations compared with all other conditions. The relative proportion of offensive and defensive players involved greatly affected search rate variables, such as the mean fixation duration and location.

Although these papers were successful in systematically manipulating certain task constraints, they only focused on the perceptual sources of information that athletes use to guide performance. There have been no attempts to provide a window into the cognitive processes that mediate perception, anticipation and decision making across the different task and situational constraints presented by the performance environment, particularly in team ball sports such as soccer. A few researchers have started to explore the cognitive processing strategies mediating superior performance in soccer although they have been conducted using a single situational constraint (e.g., North et al., 2011; Roca, Ford, McRobert, & Williams, 2011; Ward et al., 2003). These studies have revealed that experts articulate more higher-order cognitive thought strategies involving prediction, reasoning, and planning compared to lower-order processes such as the monitoring of current actions or events. In order to enhance understanding of perceptual and cognitive expertise in sport, research is needed where multiple process measures (e.g., eye-movement recording and verbal reports of thinking) are collected in conjunction with manipulations of different situational or task constraints.

With these issues in mind, the aims in the present investigation are to examine the processes underpinning perceptual and cognitive expertise and how these differ as a function of task constraints and skill level in soccer. A particular focus is on identifying whether and how the importance of the different perceptual-cognitive skills (i.e., postural cues, pattern recognition, and situational probabilities) may vary and interact in a dynamic manner during performance. A representative film-based simulation of 11 versus 11 soccer situations filmed from a player's perspective and under two different task-situation constraint scenarios (i.e., far vs. near task constraint) are presented. A combination of eye-movement data (Experiment 1) and retrospective verbal reports of thinking (Experiment 2) are collected to provide a more complete understanding of perceptual-cognitive expertise across different task constraints in soccer.

Experiment 1

In Experiment 1, differences in visual search behaviours as well as anticipation and decision making performance are examined across two distinct game situations in soccer using adult skilled and less skilled participants. It was predicted that skilled soccer players would reveal superior anticipation and decision making when compared with less skilled counterparts. It was hypothesised that during the far task condition, where the ball was far away from the participant who was in a central defensive position, skilled participants would employ more fixations of shorter duration and towards more informative areas in the scene. In the near task, where the ball was closer to the participant/central defender, they would have fewer fixations of longer duration and predominantly to the player in possession of the ball (Vaeyens et al., 2007a, b; Williams et al., 1994; Williams & Davids, 1998). For less skilled participants, it was expected no significant differences in the visual search rate and pattern (i.e., similar duration and number of fixations, and mainly towards less instructive areas of the display) employed across task conditions, due to their lack of domain- and task-specific knowledge base compared with their more skilled counterparts (Williams & Ford, 2008).

Methods

Participants

Twenty four (12 skilled and 12 less skilled) adult male soccer players participated. Skilled participants (*M* age = 23.1 years, *SD* = 3.7) were professional (*n* = 6) and semi-professional (*n* = 6) players. They had been playing soccer for an average of 14.4 years (*SD* = 3.1), during which they had trained/played for a mean of 9.7 hr (*SD* = 2.4) per week and participated in an average total of 720 (*SD* = 133) competitive matches. Less skilled players (*M* age = 24.1 years, *SD* = 2.2) had participated only at an amateur or recreational level. They had played soccer infrequently for an average of 11.0 years (*SD* = 4.2), participating in a mean total of 90 matches (*SD* = 79) and averaging 1.5 hr (*SD* = 1.5) per week in practice. Participants provided informed consent and the research procedures were conducted according to the ethical guidelines of the lead institution.

Test Film

Participants were presented with a representative video-based simulation task involving life-size video sequences of dynamic, 11 versus 11 soccer situations filmed and viewed from the perspective of a central defender (for a detail description on the creation of the test film, see Chapter 2, pp. 29-30). A panel of three Union of European Football Associations (UEFA) qualified soccer coaches independently examined and selected a total of 20 video clips. These video clips were sub-divided into two different conditions termed *far* and *near* task. In half of the clips the ball was far away from the participant or central defender (i.e., far task), whereas in the other half the ball was closer to the player or camera (i.e., near task). In the far task condition the attacking team was in possession of the ball only in their defensive half, whereas in the near task clips the action started and finished in their offensive half of the pitch (see Figure 4.1a and b). Only those sequences approved by all coaches were included. Each sequence of play lasted approximately 5 s and was occluded at a key moment in the action (e.g., player in possession of the ball about to make an attacking pass, shoot at goal, or maintain possession of the ball by dribbling forward). Video sequences were presented randomly, with the order being consistent across all participants.

(a)

(b)

Figure 4.1. A final frame extracted from a typical simulation on the (a) 'far task' and (b) 'near task' conditions.

Apparatus

The film clips were back projected using a video projection system (Hitachi ED-A101, Yokohama, Japan) onto a 2.7 m (h) x 3.6 m (w) screen (Draper Cinefold, Spiceland, IN, USA). Participants started each individual clip in a standing position at a distance of 2.5m from the screen subtending a visual angle of approximately 35° in the horizontal and 28° in the vertical direction. This set up provided a realistic environment closely simulating the real image size and distance between the player (i.e., in a central defensive position) and the action. Participants were required to take the place of the defender and move and interact with the footage as if playing in a competitive match. The movement responses of participants were monitored using a digital video camera (Canon LEGRIA FS200, Tokyo, Japan) positioned 3m behind the participant and linked to a TV monitor screen (Philips 15PF5120, Eindhoven, Netherlands) placed on the experimenter's desk.

Eye movements were recorded with a mobile eye-tracking system (Applied Science Laboratories, Bedford, MA, USA). The Mobile Eye consists of a video-based monocular system that measures eye point-of-gaze with respect to a head-mounted scene camera. The system measures the relative position of the pupil and corneal reflection in relation to each other. The result is a computed point-of-gaze superimposed as a cursor onto the scene image captured by the head-mounted camera optics. The data were analysed frame-by-frame using SportsCode Gamebreaker V8 software (Sportstec, Sydney, Australia). System accuracy was ± 1° visual angle, with a precision of 1° in both the horizontal and vertical fields.

Procedure

Prior to testing, participants were given an overview of the experiment and the eye-movement system was fitted onto the head. The system was calibrated using a reference of 6-9 nonlinear points on the scene image so that the fixation mark corresponded precisely to the participant's point-of-gaze. The calibration procedure was periodically checked between trials to ensure system accuracy. Participants were primarily presented with four practice trials to ensure familiarity with the experimental setup. At the end of each clip, participants were required to confirm 'What the player in possession was going to do?' and 'What decision the participant themselves made or were about to make at the moment of video occlusion?' Participants received 20 test trials and each individual completed the training and test session in approximately 45 min.

Outcome Data Analysis

Measures of anticipation and decision making performance were recorded. Anticipation accuracy was defined as whether or not the participant correctly selected the next action of the player in possession of the ball at the moment of video occlusion, such as he passed to a particular teammate, shot at goal, or continued dribbling the ball. For the decision making measure, the panel of UEFA qualified soccer coaches independently selected the most appropriate decision for a participant to execute in response to the action at the moment of video occlusion. The accuracy was defined as whether or not the action selection corresponded to the most appropriate decision for that trial. The inter-observer agreement between coach selections was 91.7%.

The anticipation and decision making accuracy were calculated as the mean number of trials (in %) in which the participant made the correct response. The outcome scores on each of the two measures were analysed separately using a factorial two-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Task Condition (far vs. near task) as within-participant factors.

Visual Search Data Analysis

The three most discriminating trials for each of the far and near task conditions (i.e., making six trials in total), which were chosen based on the greatest between-group differences in mean outcome scores, were subjected to visual search analysis (cf. McRobert et al., 2009).

Search rate. Three measures of search rate were examined. These were the mean number of fixations per trial, the mean number of fixation locations per trial, and mean fixation duration (in milliseconds). A fixation was defined as a condition in which the eye remained stationary within 1.5° of movement tolerance for a period equal to, or in excess of, 120 ms or 3 video frames (Williams & Davids, 1998). Each of these variables was analysed separately using a factorial two-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Task Condition (far vs. near task) as within-participant factors.

Percentage viewing time. Percentage of total viewing time spent fixating various areas of the display was also analysed. The display was initially divided into six fixation locations: player in possession of the ball; ball (i.e., ball flight); opponent player; teammate player; space (i.e., areas of free space on the pitch in which no player is located); and an unclassified category for fixations that did not match with the aforementioned locations. The unclassified category was eventually excluded because none of participants' fixations fell outside any of the other five locations. Percentage viewing time data were analysed using a factorial three-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Task Condition (far vs. near task) and Fixation Location (player in possession of the ball, ball, opponent, teammate, space) as within-participant factors.

Fixation order. Fixation order is the search sequence or pattern used by the participants. The dependent variable employed was the average frequency per trial that participants alternated their gaze between the player in possession of the ball or the ball and some other area of the display, and then back to the player in possession of the ball or ball (cf. Williams et al., 1994; Williams & Davids, 1998). Fixation order data were analysed using a factorial two-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Task Condition (far vs. near task) as within-participant factors.

The reliability of the visual search data was established using the intra- (95.2%) and inter-observer (91.0%) agreement methods. Altogether, just over 25.0% of the data were re-analysed to provide these figures using the procedures recommended by Thomas et al. (2005). For any repeated measures ANOVA, Greenhouse-Geisser procedures were used to correct for violations of the sphericity assumption. Effect sizes were reported as partial eta squared (η_p^2). Any significant main and interaction effects were followed up using Bonferroni corrected pairwise comparisons and Tukey's HSD post hoc tests, respectively. The alpha level was set at $p < .05$.

Results and Discussion

Outcome Data

As predicted, skilled participants were more accurate than less skilled participants at anticipating the actions of their opponents (M = 68.3%, SD = 7.2 vs. M = 37.5%, SD = 6.6), $F(1, 22) = 120.47$, $p < .001$, $\eta_p^2 = .85$. Skilled participants were also more accurate than less skilled in deciding on how to respond to each game-situation (M = 80.8%, SD = 5.1 vs. M = 49.2%, SD = 9.7), $F(1, 22) = 99.28$, $p < .001$, $\eta_p^2 = .82$. A significant main effect for type of task was revealed for anticipation accuracy, $F(1, 22) = 20.13, p < .001, \eta_p^2 = .48$. Participants were more accurate when interacting with the near task ($M = 61.7\%$, $SD = 19.0$) compared with the far task clips ($M = 44.2\%$, $SD = 19.9$). No other significant main and interaction effects were found, all $F \leq 1.23, p \geq .28, \eta_p^2 \leq .05$.

Findings support previous research using realistic film simulations of soccer situations to independently measure superior anticipation (Ward & Williams, 2003; Williams et al., 1994) and decision making (Helsen & Starkes, 1999; Vaeyens et al., 2007a). It could be speculated that as a result of their sport-specific experience, skilled players develop a sophisticated domain task-specific knowledge base that enable them to better perceive and interpret situational information previously experienced (Williams & Ward, 2007).

Visual Search Data

Search rate. The mean data for search rate variables are presented in Table 4.1. There were significant skilled-based differences in the mean fixation duration, $F(1, 22) = 40.16, p < .001, \eta_p^2 = .65$, the mean number of fixations, $F(1, 22) = 76.41$, $p < .001, \eta_p^2 = .78$, and mean number of fixation locations per trial, $F(1, 22) = 75.12$, $p < .001, \eta_p^2 = .77$. The visual search behaviour of skilled players involved more fixations ($M = 11.06$ fixations, $SD = 3.46$ vs. $M = 6.32$ fixations, $SD = 1.32$) of shorter duration ($M = 465$ ms, $SD = 200$ vs. $M = 811$ ms, $SD = 183$) to significantly more locations in the visual display ($M = 5.72$ fixation locations, $SD = 1.92$ vs. $M = 3.32$ fixation locations, $SD = 0.76$) when compared with the less skilled players. There was also a significant main effect for task condition in the average fixation duration, $F(1, 22) = 27.66, p < .001, \eta_p^2 = .56$, the average number of fixations, $F(1, 22) = 132.33, p < .001, \eta_p^2 = .86$, and average number of fixation locations per trial,

$F(1, 22) = 52.92$, $p < .001$, $\eta_p^2 = .71$. Participants made more fixations (M = 10.48 fixations, SD = 3.86 vs. M = 6.90 fixations, SD = 1.96) of shorter duration (M = 539 ms, SD = 246 vs. M = 737 ms, SD = 234) and on more locations in the display (M = 5.42 fixation locations, SD = 2.33 vs. M = 3.63 fixation locations, SD = 0.79) during the far task when compared with the near task condition.

Significant Group x Task Condition interaction effects were observed for the mean fixation duration, $F(1, 22) = 4.42$, $p = .047$, $\eta_p^2 = .17$, the mean number of fixations, $F(1, 22) = 50.49$, $p < .001$, $\eta_p^2 = .70$, and mean number of fixation locations per trial, $F(1, 22) = 31.05$, $p < .001$, $\eta_p^2 = .59$. Post hoc testing revealed that skilled players used significantly more fixations of shorter duration and towards greater number of locations when interacting with the far task clips compared with the near clips. In contrast, less skilled participants showed only a modest difference in the average number of fixations per trial between the far and near task clips. There were no differences for the less skilled for the average fixation duration and average number of fixation locations per trial. These data support previous research involving the analysis of visual search behaviours when different skill-based soccer players viewed simulations of the whole field of play (i.e., 11 vs. 11 simulations; e.g., Williams et al., 1994) compared with micro situations within the game (e.g., 3 vs. 3, 3 vs. 1, or 2 vs. 1 situations; see Vaeyens et al., 2007a, b; Williams & Davids, 1998).

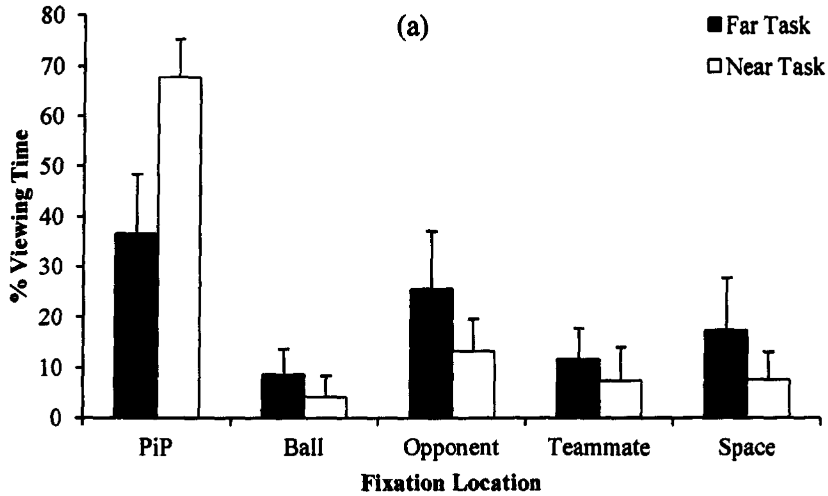
Table 4.1

Mean (SD) Number of Fixations, Number of Fixation Locations, and Fixation Duration per Trial Across Groups and Task Conditions

	Skilled		Less skilled	
Search rate	Far task	Near task	Far task	Near task
No. of fixations	13.95 (1.92)	8.17 (1.85)	7.01 (1.23)	5.64 (1.05)
No. of fixation locations	7.31 (1.37)	4.14 (0.58)	3.53 (0.83)	3.11 (0.64)
Fixation duration (ms)	332 (61)	598 (205)	745 (174)	877 (173)

Percentage viewing time. The mean data for percentage viewing time are presented in Figure 4.2. There was a significant main effect for fixation location, $F(2.35, 51.72) = 219.26$, $p < .001$, $\eta_p^2 = .91$. Bonferroni corrected pairwise comparisons demonstrated that participants spent significantly more time fixating the player in possession of the ball (M = 56.4%, SD = 16.9) in comparison with any other fixation location. This was followed by fixations on the ball (M = 17.3%, SD = 15.0) and opponents (M = 12.5%, SD = 10.9), respectively. No difference was evident between fixations on teammates (M = 6.5%, SD = 6.4) and areas of free space (M = 7.4%, SD = 8.6). There was also a significant Group x Fixation Location interaction effect, $F(2.35, 51.72) = 27.55$, $p < .001$, $\eta_p^2 = .56$. Post hoc testing showed that less skilled players spent significantly more time fixating the player in possession of the ball (M = 60.6%, SD = 14.1) and the ball's course of action (M = 28.1%, SD = 13.7) compared with the skilled players (M = 52.2%, SD = 18.6 and M = 6.4%, SD = 5.2, respectively). In contrast, skilled participants spent significantly more time fixating on the opponents (M = 19.3%, SD = 11.2) and areas of free space (M = 12.5%, SD = 9.7) when compared with the less skilled group (M = 5.6%, SD = 4.2 and M = 2.3%, SD = 2.0, respectively).

A significant Group x Task Condition x Fixation Location interaction was observed, $F(2.06, 45.23) = 5.45$, $p = .007$, $\eta_p^2 = .20$. Post hoc testing revealed that in the far task, skilled players spent more time fixating teammates, opponents and areas of free space combined ($M = 54.7\%$, $SD = 12.2$ vs. $M = 28.0\%$, $SD = 7.0$), whereas in the near task, they spent more time fixating the player in possession of the ball ($M = 67.8\%$, $SD = 7.4$ vs. $M = 36.6\%$, $SD = 8.7$). In comparison, less skilled participants showed no significant differences for the time spent fixating on the different locations of the display between the far and near task clips. No other main and interaction effects were significant, all $F \leq 0.31$, $p \geq .58$, $\eta_p^2 \leq .01$.



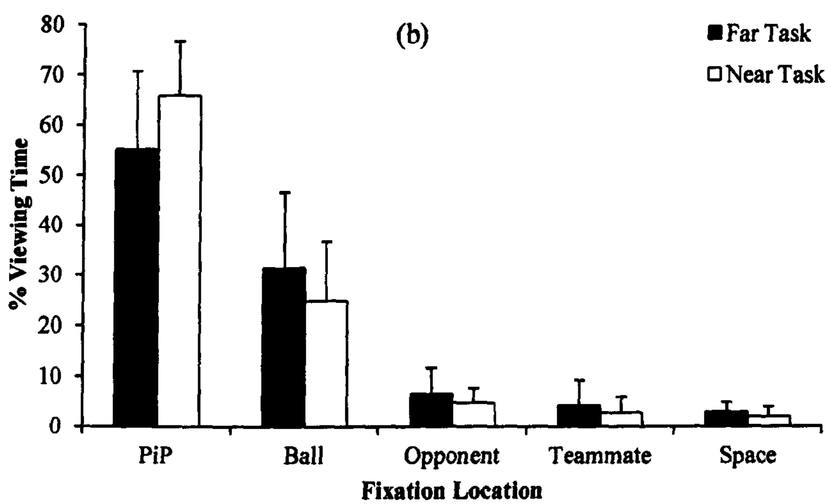


Figure 4.2. Mean (SD) percentage of time spent viewing each fixation location across task conditions for (a) skilled and (b) less skilled players. (*PiP* player in possession of the ball).

Fixation order. Skilled participants (M = 1.8 fixation switches, SD = 0.5) alternated their gaze more frequently between the player in possession of the ball or ball and any other area of the display when compared with less skilled participants (M = 0.4 fixation switches, SD = 0.5), $F(1, 22) = 88.57, p < .001, \eta_p^2 = .80$. No other main and interaction effects were significant, all $F \leq 1.21$, $p \geq .28$, $\eta_p^2 \leq .05$. This skill-based difference in fixation order was reported in previous studies (e.g., Vaeyens et al., 2007a, b; Williams et al., 1994).

The findings of this experiment highlighted a number of systematic differences in visual search strategies as a function of skill level and the unique constraints of the task. According to the results, skilled soccer players employ different visual search strategies when viewing the whole field of play (i.e., far task) compared with more microstates of play (i.e., near task). When the ball is far away from the player, they used a search pattern involving more fixations of relatively shorter duration possibly so as to become fully aware of the positions and movements of players on and off the ball. In contrast, when the ball is closer to the player, they employed lower search rates, generally fixating gaze centrally on the player in possession of the ball, and perhaps relying on peripheral vision to monitor the players' movements (Williams & Davids, 1998). These findings indicated that the search patterns employed appears to be strongly governed by the constraints of the task as well as the skill level of the performer. The manipulation of the distance between the ball and player and/or goal resulted in a more complete representation of the processes mediating expertise in 11 versus 11 soccer situations.

Experiment 2

In Experiment 2, the thought processes that underpin anticipation and decision making expertise across different task constraints were examined. Particular attention was given for the first time in the literature to examining how the different perceptual-cognitive skills interact during performance as a function of the unique constraints imposed by the task (i.e., far vs. near task). The collection of verbal reports of thinking is expected to further understanding of how different situational task constraints influence the nature and processes mediating expert performance. It was hypothesised that skilled players' more enhanced domain-specific memory representations would be evidenced by the verbalisation of a superior number of cognitive verbal statements across tasks (North et al., 2011; Roca et al., 2011; Ward et al., 2003). It was also expected that due to the more attention-demanding and temporal pressure situation of the near task, skilled players would articulate a greater number of higher-order cognitive statements when compared to the far task condition.

In a subsequent analysis involving a new classification scheme of verbal reports, specifically developed to examine the interaction between perceptual-cognitive skills, it was hypothesised that the importance of these skills would alter significantly depending on the specific constraints of the task (Williams, 2009). This hypothesis was based on the results of Experiment 1 and the findings of previous studies involving the recording of eye-movement behaviour during different game constraints in soccer (e.g., Vaeyens et al., 2007a; Williams & Davids, 1998; Williams et al., 1994). According to these findings, different search strategies are employed when viewing the whole field of play (i.e., far task; 11 vs. 11 simulations) compared to more time-constrained micro-situations of the performance setting (e.g., near task; 3 vs. 3 or 1 vs. 1 duels), where the specificity and nature of the task is an important constraint on the type of search pattern used by players. It was predicted that in the far task clips players would be expected to rely more so on pattern recognition skills due to their fixating on multiple players in this condition during Experiment 1. In the near task, they were expected to rely on postural cue usage due to their mainly fixating the player in possession of the ball in Experiment 1. Finally, there is comparatively little research on situational probabilities and the work that exists has typically identified skill-based differences rather than exploring whether the importance of these probabilities differ from one situation/task to another. Consequently, no predictions were made for the relative importance of situational probabilities across task conditions.

Methods

Participants

Twenty four (12 skilled and 12 less skilled) adult male soccer players were recruited. None of these participants took part in Experiment 1, although these participants were of the same skill level compared with the previous sample. Skilled participants (*M* age = 23.6 years, *SD* = 4.4) were professional (*n* = 7) and semi-professional (*n* = 5) players. They had an average of 14.8 years (*SD* = 3.9) playing experience, during which they had trained/played for a mean of 10.3 hr (*SD* = 2.6) per week and participated in an average total of 730 (*SD* = 138) competitive matches. Less skilled players (*M* age = 24.5 years, *SD* = 3.7) had not participated in the sport above amateur or recreational level. They had played soccer irregularly for an average of 11.3 years (*SD* = 3.2), including participation in a mean total of 80 matches (*SD* = 74). They currently played for an average of 1.7 hr (*SD* = 1.6) per week. Participants provided informed consent and the research procedures were conducted according to the ethical guidelines of the lead institution.

Test Film

The test film was the same as in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1. Verbal reports were collected by using a lapel wireless microphone set (Sennheiser EW-100G2, Wedemark, Germany), including a telemetry radio transmitter fixed to the participant and a telemetry radio receiver connected to the digital video camera.

Procedure

Prior to completing the experimental tasks, participants were instructed and trained on how to think aloud and provide retrospective verbal reports. The instruction and training protocol comprised Ericsson and Kirk's (2001) adaption of Ericsson and Simon's (1993, pp. 375-379) original protocol. The training session included instruction and practice on thinking aloud and giving immediate retrospective verbal reports by solving a range of both generic- and domain-specific tasks (for an extended review, see Eccles, 2012). The verbal report training protocol lasted approximately 30 min.

At the end of the instruction phase, four practice trials ensured that participants were familiar with the experimental setting and the protocol procedure. Retrospective verbal reports were collected directly after each trial. Testing sessions were carried out individually in a quiet room and were completed in approximately 60 min.

Outcome Data Analysis

The measures of performance were the same as in Experiment 1.

Verbal Report Data Analysis

An individual unfamiliar with the experiment transcribed each participant's statements verbatim after completion of the experiment. In order to ensure the transcriptions were accurate, another individual with no knowledge of the experiment verified the statements. The three most discriminating trials per task condition (far vs. near task) that were chosen based on the greatest between-group mean outcome scores from the anticipation and decision making measures were used for verbal analysis (cf. McRobert et al., 2009). These trials were subsequently coded for each participant using the protocol analysis method described by Ericsson and Simon (1993). The transcriptions of retrospective verbal reports were segmented using natural speech and other syntactical markers. Verbal reports were then categorically coded on two separate classification schemes, namely types of cognition and interaction of perceptual-cognitive skills.

Cognitions. Participants' verbal reports were categorically coded based on a structure originally adapted from Ericsson and Simon (1993) and further developed by Ward et al. (2003). This included four major types of cognitive statement categories: (a) *monitoring statements* were those recalling current actions or descriptions of current events; (b) *evaluations* were statements making some form of comparison, assessment, or appraisal of events that are situation, task, or context relevant; (c) *predictions* referred to statements anticipating or highlighting future or potential future events; and (d) *planning statements* were those referring to a decision(s) on a course of action in order to anticipate an outcome or potential outcome event.

Interaction of perceptual-cognitive skills. In order to analyse the interactions between the different perceptual-cognitive skills during performance, retrospective reports were also classified based on a refined encoding/categorisation system inductively developed to highlight statements made about key perceptual-cognitive skills (cf. Yang, 2003). These were classified according to three major concept categories: (a) *postural cues* reflected all statements referring to cue sources emanating from bodily form, e.g., 'player shaped to pass long'; (b) *pattern recognition* reflected all statements representing relational information or an interaction between two or more players on the same team, e.g., 'play switched across the back-four'; and (c) *situational probabilities* were those statements that referred to the likelihood of a particular event occurring in future, e.g., 'striker in a good position to receive the ball'.

The reliability of the data was established using the same methods as in Experiment 1. For the cognition and interaction of perceptual-cognitive skills scheme the intra-observer reliability was reported as 93.2% and 94.4% respectively and for the inter-observer reliability, 89.0 vs. 83.6%. More than 25.0% of the data were re-analysed for both sets of verbal reports' coding (Thomas et al., 2005). These classification schemes were analysed separately using a factorial three-way ANOVA with Group (skilled, less skilled) as the between-participant factor and Task Condition (far vs. near task) and Type of Verbal Statement (monitoring, evaluation, prediction, planning; or postural cues, pattern recognition, situational probabilities) as within-participant factors. Greenhouse-Geisser procedures were used to correct for violations of the sphericity assumption. Significant main and interaction effects were followed up as in Experiment 1 and effect sizes were reported as partial eta squared (η_p^2).

Results and Discussion

Outcome Data

Skilled players were more accurate than less skilled counterparts at anticipating the actions of opponents (M = 69.3%, SD = 7.8 vs. M = 34.9%, SD = 9.0), $F(1, 22) = 100.24$, $p < .001$, $\eta_p^2 = .82$. Skilled players were also more accurate compared with less skilled players in deciding on an appropriate tactical decision (M = 82.8%, SD = 8.9 vs. M = 50.5%, SD = 6.2), $F(1, 22) = 106.24$, $p < .001$, $\eta_p^2 = .83$. Participants were more accurate in anticipating the actions of their opponents during the near task (M = 61.5%, SD = 19.8) compared with the far task condition (M = 44.7%, SD = 25.7), $F(1, 22) = 13.84, p = .001, \eta_p^2 = .39$. No other interaction effects were significant, all $F \leq 1.07, p \geq .31, \eta_p^2 \leq .05$.

Verbal Report Data

Cognitions. There was a significant main effect for group, $F(1, 22) = 43.16, p < .001, \eta_p^2 = .66$. Skilled participants ($M$ = 7.21 statements, SD = 1.51) generated significantly more cognitive statements compared with the less skilled group (M = 4.71 statements, SD = 1.21). These results support the experiment's initial predictions and are indicative of skilled players possessing and engaging in more complex domain- and task-specific memory representations to solve the task when compared with less skilled players. A significant main effect for type of verbal statement was observed, $F(2.06, 45.27) = 269.90, p < .001, \eta_p^2 = .93$. Bonferroni corrected pairwise comparisons showed that participants generated significantly more monitoring statements (M = 3.33 statements, SD = 0.86) than all other statement types. After monitoring statements, predictive statements (M = 1.09 statements, SD = 0.60) were most frequently articulated. No differences were evident between the number of evaluations (M = 0.67 statements, SD = 0.62) and planning statements (M = 0.87 statements, SD = 0.57) articulated. Participants also generated more verbal statements when viewing the near task (M = 6.58 statements, SD = 1.91) compared with the far task clips (M = 5.33 statements, SD = 1.60), $F(1, 22) = 14.61, p = .001, \eta_p^2 = .40$. There was also a significant Task Condition x Type of Verbal Statement interaction effect, $F(1.91, 41.99) = 4.88, p = .013, \eta_p^2 = .18$. Post hoc testing showed that participants verbalised significantly more predictive (M = 1.39 statements, SD = 0.64 vs. M = 0.79 statements, SD = 0.38) and planning statements

($M = 1.17$ statements, $SD = 0.60$ vs. $M = 0.57$ statements, $SD = 0.35$) during the near task in comparison with the far task condition.

A significant Group x Task Condition x Type of Verbal Statement interaction effect was observed, $F(1.91, 41.99) = 3.77$, $p = .033$, $\eta_p^2 = .15$. Post hoc testing revealed that skilled players generated significantly more predictive and planning statements when interacting with the near task compared with the far task clips. No differences were revealed for less skilled players in the type of verbal statements made across task conditions. These data are presented in Table 4.2. No other interaction effects were significant, all $F \leq 0.73$, $p \geq .40$, $\eta_p^2 \leq .03$. These differences appear to be due to the more attentionally demanding and time-constrained situation presented by the near task, leading skilled players to direct greater attention on information prediction within the display and stimulate richer and more complex retrieval processes from memory in order to plan and formulate an appropriate decision under pressure. On the other hand, less skilled players were unable to employ such advanced task-specific problem representations of the actual game in order to promote elaborative encoding of critical contextual information (e.g., McPherson & Kerondle, 2003, 2007; McRobert et al., 2011; Ward et al., 2011).

Table 4.2

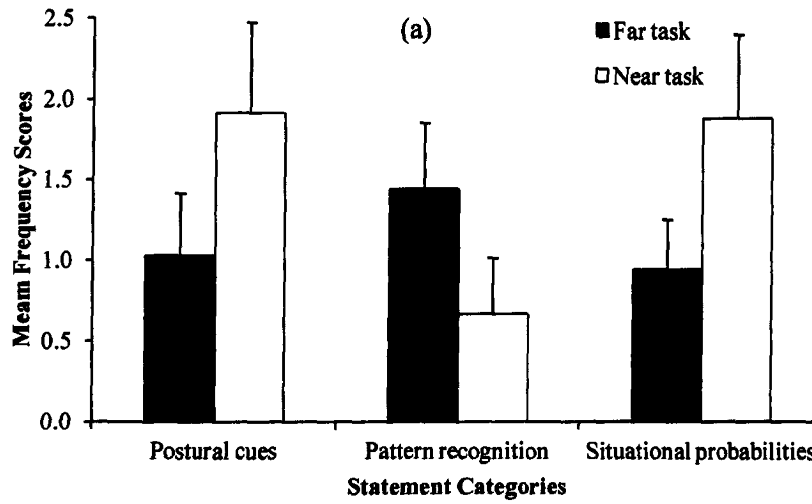
Mean (SD) Frequency Scores per Trial for Type of Verbal Statement Across Groups and Task Conditions on the Cognitions Classification Scheme

	Skilled		Less skilled	
Type of verbal statement	Far task	Near task	Far task	Near task
Total statements	6.44 (1.25)	7.97 (1.40)	4.22 (1.04)	5.19 (1.21)
Monitoring	3.64 (0.73)	3.50 (1.00)	2.86 (0.73)	3.31 (0.82)
Evaluation	1.11 (0.57)	0.94 (0.69)	0.33 (0.32)	0.31 (0.41)
Prediction	0.94 (0.31)	1.86 (0.50)	0.64 (0.39)	0.92 (0.35)
Planning	0.75 (0.32)	1.67 (0.45)	0.39 (0.28)	0.67 (0.28)

Interaction of perceptual-cognitive skills. These data are highlighted in Figure 4.3. There was a significant main effect for group, $F(1, 22) = 37.85$, $p < .001$, $\eta_p^2 = .63$. Skilled participants (M = 3.94 statements, SD = 1.01) generated significantly more perceptual-cognitive skills statements compared with the less skilled group (M = 2.39 statements, SD = 1.06). A significant main effect for type of verbal statement was observed, $F(2, 44) = 22.36$, $p < .001$, $\eta_p^2 = .50$. Bonferroni corrected pairwise comparisons demonstrated that participants generated more postural cues (M = 1.33 statements, SD = 0.70) and situational probability statements (M = 1.11 statements, SD = 0.61) in comparison with pattern recognition statements (M = 0.68 statements, SD = 0.58). Participants also generated more verbal statements when viewing the near task (M = 3.58 statements, SD = 0.80) compared with the far task clips (M = 2.75 statements, SD = 0.51), $F(1, 22) = 16.24$, $p = .001$, $\eta_p^2 = .43$. Interestingly, results revealed a significant Task Condition x Type of Verbal Statement interaction effect, $F(2, 44) = 36.31$, $p < .001$, $\eta_p^2 = .62$. Post hoc testing showed that participants verbalised significantly more postural cues (M = 1.71

statements, $SD = 0.72$ vs. $M = 0.96$ statements, $SD = 0.43$) and situational probability statements ($M = 1.40$ statements, $SD = 0.66$ vs. $M = 0.81$ statements, $SD = 0.37$) during the near task compared to the far task condition. In contrast, more pattern recognition statements ($M = 0.89$ statements, $SD = 0.67$ vs. $M = 0.47$ statements, $SD = 0.37$) were made in the far task in comparison with near task.

A the significant Group x Task Condition x Type of Verbal Statement interaction effect was also observed, $F(2, 44) = 11.92$, $p < .001$, $\eta_p^2 = .35$. Post hoc testing revealed that skilled players generated a greater number of statements relating to postural cues ($M = 1.92$ statements, $SD = 0.56$ vs. $M = 1.03$ statements, $SD = 0.39$) and situational probabilities ($M = 1.89$ statements, $SD = 0.52$ vs. $M = 0.95$ statements, $SD = 0.31$) during the near task compared with the far. During the far task, they made more pattern recognition statements ($M = 1.44$ statements, $SD = 0.41$) compared with the near task condition ($M = 0.67$ statements, $SD = 0.35$). Although less skilled players verbalised more postural cues ($M = 1.50$ statements, $SD = 0.63$ vs. $M = 0.89$ statements, $SD = 0.48$) during the near task compared with far, no differences were evident for the number of pattern recognition ($M = 0.28$ statements, $SD = 0.28$ vs. $M = 0.33$ statements, $SD = 0.32$) and situational probability statements ($M = 0.92$ statements, $SD = 0.35$ vs. $M = 0.67$ statements, $SD = 0.38$) generated across the two tasks. No other interaction effects were significant, all $F \leq 3.05$, $p \geq .06$, $\eta_p^2 \leq .12$. These results reveal, with skilled participants in particular, the existence of a highly dynamic interaction between the different perceptual-cognitive skills during performance, with their relative importance varying significantly from one situation to the next depending on the unique constraints of the task.



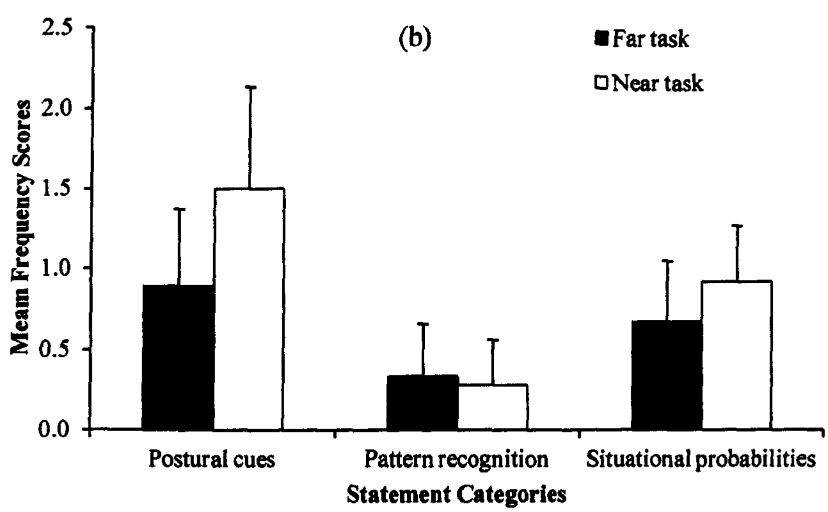


Figure 4.3. Mean (SD) frequency scores per trial for type of verbal statement across groups and task conditions on the interaction of perceptual-cognitive skills classification scheme for (a) skilled and (b) less skilled players.

Overall, the data of this experiment suggest that skilled players activate more elaborate domain- and task-specific problem representations of the game from memory compared with the less skilled counterparts. The importance of different perceptual-cognitive skills was varied as a function of the unique constraints imposed by the game. It appears that perceptual-cognitive expertise within a particular domain is accompanied by the development of a range of complex situational and task-specific knowledge representations and skills that guide input and retrieval of pertinent information from the visual scene and from memory in an integrated manner (Ericsson & Lehmann, 1996).

General Discussion

In this paper, the visual search behaviours and cognitive thought processes employed by skilled and less skilled soccer players across different situational task constraints (i.e., far vs. near task conditions) in soccer were examined. A prime focus was to examine whether and how the different perceptual-cognitive skills interact in a continuous manner to facilitate appropriate anticipation and decision making. Based on previous research involving the analysis of visual search behaviours during film-based soccer simulations (Vaeyens et al., 2007a, b; Williams & Davids, 1998), it was predicted that the superior performance of skilled players would be caused by systematic differences in the underlying perceptual and cognitive processes as a function of the task presented. It was further expected that these perceptual-cognitive skills would reveal an interaction with each other during performance, with their relative use altering from one situation to the next. The latter aim was particularly novel in the sense that it marks an initial attempt to look at the relative interaction between perceptual-cognitive skills in sport, rather than examine the importance of each of these skills in isolation from the other (Williams, 2009).

Skilled participants were more accurate than less skilled players at anticipating the actions of their opponents and deciding on an appropriate course of action. As expected, the data revealed a number of systematic differences in visual search behaviours between skilled and less skilled players across task constraints.

Skilled players employ more fixations of shorter duration and towards greater number of locations in the display (i.e., opponents, teammates, and areas of free space) when interacting with the far task compared with the near task condition. On the other hand, when viewing the near task clips, skilled players typically employed fewer fixations of longer duration and mostly towards the player in possession of the ball. In contrast, less skilled players tended to be guilty of 'ball watching' in both conditions, with the only difference being in the number of fixations across the two tasks.

In accordance with the initial predictions, skilled soccer players also demonstrated to have engaged in a greater number of cognitive statements, suggesting that they were using sophisticated memory representations of the game, which are presumed to be crucial to help guide the search for and effective processing of task-specific information (see Roca et al., 2011; Ward et al., 2003). Moreover, skilled players were shown to engage in more predictive and planning statements during the near task compared with the far task. Finding may be associated with the more dynamic and severe temporal constraint of the near task condition compared to the far due to the closer existing distance between the ball position, as key reference of the game, and the player/participant. These findings support the argument that skilled players are more capable than less skilled players in adapting their visual search and cognitive processing strategies in relation to the distinctive constraints of the task (Ericsson & Lehmann, 1996; Williams et al., 2011).

The different perceptual-cognitive skills were observed to interact in a dynamic and continuous manner during performance, with their importance varying as a function of the task constraint. In the far task, skilled players in particular generated more thought processes related to the recognition of structure or patterns within evolving sequences of play. In the near task, these players made more statements about the postural orientation of opponents/teammates, followed by expectations as to what their opponents are likely to do in advance of the actual event (i.e., situational probabilities). The results regarding the pattern recognition and postural cues thought processes appear to be confirmed by the visual search analyses in Experiment 1. Skilled participants fixated their gaze on more disparate and informative areas of the display when viewing the whole field of play in the far task, implying a tendency to identify familiarity and structural relations between features, such as the positions and/or movement patterns of players (North et al., 2011). In contrast, when the ball was closer to the player in the near task, they employed lower search rates, generally focusing gaze on the player in possession, perhaps picking up information from their postural orientation ahead of a key event such as foot-ball contact. On the other hand, less skilled players showed no difference in the number of pattern recognition statements verbalised in both tasks.

No hypothesis was made as regards to the relative importance of situational probabilities across task conditions. It could be speculated that differences in the weight of situational probabilities for skilled players across the two tasks is related to changes in the cost-benefit ratio associated with accurate and inaccurate anticipation and decision making judgments depending on the specificity of the task involved. For example, when the ball is in the other half of the field, there is probably very little cost as well as benefit in generating probabilities because the ball is far away and there is plenty of time available. In contrast, when the ball is nearer the goal, the benefit of assigning probabilities may increase because it may provide more time to formulate and select the most accurate response.

Findings have significant implications for the manner in which researchers and those involved in the training process try to capture and develop perceptual-cognitive skills across a range of domains. If the different perceptual-cognitive skills interact in a dynamic and continuous manner during performance, and as a function of a range of factors and constraints, then the actual value of measuring and/or training any of these skills in isolation may be an issue to take into account. In future, scientists and all those involved in the training and development process should take into account the interaction of the different perceptual-cognitive skills and its components when designing test and training interventions, perhaps by designing or developing tasks where the key perceptual-cognitive skills are trained together in the manner they would be used during actual performance, rather than the isolation of a particular component/skill.

In summary, skilled soccer players made more accurate anticipations and decisions compared to less skilled players, which was underpinned by quantitative differences in perceptual and cognitive processes that were unique to the constraints of the task. The different perceptual-cognitive skills interacted during performance with the relative importance of each altering as a function of the game situation or task presented. The approach adopted was innovative and provides an important conceptual contribution to models of expertise and expert performance in sport.

Chapter 5

Developmental Activities and the Acquisition of Superior Anticipation and Decision Making in Soccer Players

Abstract

This study aimed to examine whether soccer players with varying levels of perceptual-cognitive expertise can be differentiated based on their engagement in various types and amounts of activity during their development. A total of 64 participants interacted with life-size video clips of 11 versus 11 dynamic situations in soccer, viewed from the first-person perspective of a central defender. They were required to anticipate the actions of their opponents and to make appropriate decisions as to how best to respond. Response accuracy scores were used to categorise elite players (n = 48) as high- (n = 16) and low-performing (n = 16) participants. A group of recreational players (n = 16) who had lower response accuracy scores compared to the elite groups acted as controls. The participation history profiles of players were recorded using retrospective recall questionnaires. The average hours accumulated per year during childhood in soccer-specific play activity was the strongest predictor of perceptual-cognitive expertise. Soccer-specific practice activity during adolescence was also a predictor, albeit its impact was relatively modest. No differences across groups were reported for number of other sports engaged in during development, as well as for some of the key milestones achieved. A number of implications for talent development are discussed.

Keywords: *expert performance, skill development, perceptual-cognitive expertise*

The ability of a performer to predict what is likely to happen prior to an event occurring and formulate and execute an appropriate action/response in a given situation is crucial to superior performance in soccer (Roca, Ford, McRobert, & Williams, in press; Williams & Ward, 2007). It is well documented that expert soccer players (and athletes from other sports) have demonstrated superiority over lesser skilled players in their ability to anticipate and make decisions (e.g., Helsen & Starkes, 1999; Williams & Davids, 1998; Vaeyens et al., 2007b). The ability to anticipate and make decisions is presumed to be particularly important at the elite level in soccer, where these components of performance are more likely to discriminate players compared to anthropometric and physiological characteristics (Reilly, Williams, Nevill, & Franks, 2000). Most recently, researchers have started to examine how these perceptual-cognitive skills are acquired by expert athletes (e.g., Ford et al., 2010a). In this study, an attempt to extend work in this area is made by examining whether elite soccer players categorised as either high- or low-performing based on their performance on a film-based test of anticipation and decision making can be differentiated based on the amount and/or type of activity undertaken during their development.

The majority of work that does exist on the nature of the acquisition processes underpinning expert performance has relied greatly on the deliberate practice framework introduced by Ericsson et al. (1993). In this framework, retrospective recall methods (e.g., questionnaires, interviews, and training logs) are used to study the participation history profiles of elite performers in terms of the amount of hours they have spent in domain-specific activities during their development. Ericsson et al. (1993) demonstrated that the amount of deliberate practice accumulated by musicians at the Berlin Music Academy was monotonically related to their attained level of expertise. After 10 years of engagement in the domain, the best violinists had accrued a greater amount of practice (7,410 hr) compared to the good violinists (5,301 hr), and music teachers (3,420 hr). The best violinists reported that at 23 years of age they were spending around 24 hr per week in solitary deliberate practice, whereas the music teachers were spending a mere 9 hr per week. The authors classified *deliberate practice* as an activity designed to improve a specific aspect of current performance, which requires from performers their maximum attention, effort, and concentration, including gradually refined repetitions and feedback (for reviews, see Ericsson, 2007a, b; Ericsson, Nandagopal, & Roring, 2009).

The retrospective recall methodology was used by Weissensteiner et al. (2008) to examine whether differences in the ability of cricket batters to make anticipation judgments could be explained by participation history profiles. Skilled and lesser skilled cricket batters from three different age groups (under 15 years, under 20 years, and adult age groups) completed a film-based anticipation test, as well as a semi-structured interview to record their participation activity histories in sport (Côté et al., 2005). The hours accumulated in organised, cricket-specific activities (i.e., deliberate practice and competition) accounted for a relatively modest proportion (13.3%) of the variance in performance on the anticipation test. The inclusion of participant age increased the explained variance by a further 6.9%, with the skilled U20 and adult players showing superior anticipation scores compared with all other age/skill groups. The hours accumulated in informal cricket activity and formal non-sport specific practice did not explain variation in anticipation performance. The authors presented a number of possible explanations for the weak link between anticipation and practice, particularly the use of a single/incomplete measure of perceptual-cognitive expertise (i.e., postural cues underlying anticipatory skill).

In a similar study, Berry et al. (2008) examined the developmental activities engaged in by 32 Australian Football League (AFL) players who had been classified using coach ratings as either expert or less expert in regard to their perceptual-cognitive expertise. Although no differences were evident between groups in the hours accumulated in Australian Rules football, the expert group accumulated more hours during their developing years in structured activities of all types, in structured activities involving invasion-type sports, in invasion-type deliberate play, and in invasion activities from sports other than Australian football. Superior perceptual-cognitive expertise in this sport co-occurred with greater amounts of invasion sports activity that was independent of the intent during (i.e., skill development or fun) and specificity of the activity to the primary sport.

Weissensteiner et al. (2008) and Berry et al. (2008) used the subjective judgments of coaches to create expert and novice groups, which may be susceptible to systematic biases, such as the coach-athlete relationship or the athlete's personality (for a review, see Ericsson, 2003a). The selection of players into groups based on subjective criteria may lead to individuals being classified incorrectly and there would appear to be clear advantages in using objective measures of performance (Ericsson, 2003a). Ford et al. (2010a) used this method to examine the types and amounts of developmental activities that co-occurred with the acquisition of superior anticipation ability of 45 elite cricket batters. The batters were stratified into high- (n = 15) and low-performing anticipators (n = 15) based on the rank order of their response accuracy scores on a film-based test of anticipation. The Participation History Questionnaire (PHQ) revealed that during childhood there were no between-group differences for accumulated hours in cricket activities and other sports. However, activity differences were apparent in early adolescence, with the high-performing anticipators accumulating more hours in structured cricket activity compared to the low-performing. Moreover, the high-performing group accumulated more hours of their structured activity in batting practice and match-like batting practice, when compared with their low-performing peers, who accumulated more of their hours in 'net' activities (i.e., activity in which the batter faces a bowling machine or bowler on a wicket closely surrounded by netting and no fielders). Moreover, because of these between-group differences in the amount of structured activity during adolescence, high-performing anticipators accumulated more total hours in cricket activity compared to low-performing anticipators. It appears that the structure and type of activity in which players engage (e.g., Ford et al., 2010b) as well as the amount of activity accumulated differentiates high- from low-performing anticipators.

These investigations examined the relationship between antecedent activities and anticipation ability only. It is important to integrate and examine the antecedents of other components of expert performance, in particular decision making in order to provide a more complete illustration of perceptual-cognitive expertise within a particular sport (Williams & Ward, 2007). Moreover, researchers have identified another type of activity that appears to contribute to the development of expert performance: deliberate play. Côté and Hay (2002) defined *deliberate play* (e.g., street soccer/basketball) as an activity engaged in with the intention of fun and enjoyment, usually led by the children themselves. This deliberate play activity has been shown to occur in the primary sport for attainment of expertise or in various sports and there is varying levels of support for the importance of both of these types of play activity.

In Canada, North America, and Australia researchers have shown that experts accumulate more time in deliberate play activity in various sports (i.e., 'early diversification', Côté, 1999) during childhood when compared to less expert counterparts. For example, expert ice hockey players in Canada engage in six other sports during childhood (Soberlak & Côté, 2003). This diversification is hypothesised to contribute to the development of perceptual-cognitive skills through transfer of this ability between sports of a similar nature (e.g., Berry et al., 2008). In contrast, Ford, Ward, Hodges, and Williams (2009) examined the participation history profiles of elite soccer players in the United Kingdom who progressed to professional status at 16 years of age and those who did not. They reported that the elite players who went on to be offered a professional contract accumulated more hours per year in childhood in soccer-specific deliberate play, but not in soccer practice, competition or other sports compared with those who did not progress. The elite groups engaged in greater amounts of soccer-specific deliberate practice during childhood compared to a recreational control group, but not soccer play or engagement in other sports. The authors hypothesised that engagement in deliberate play in the primary sport during childhood may contribute to the acquisition of perceptual-cognitive skills, such as decision making. A need exists to examine the developmental activities that co-occur and may contribute to anticipation and decision making in order to create evidence for practitioners on the best way to develop these skills in young players.

The aim of the current study is to examine whether soccer players with varying levels of perceptual-cognitive expertise can be differentiated based on their engagement in various types and amounts of activity during their development. Skilled and recreational participants were required to move and interact with life-size, action sequences of 11 versus 11 soccer situations filmed from the first-person perspective of a defender. The accuracy of players in anticipating the actions of their opponents and in making decisions about how they themselves should respond was measured. Performance on the anticipation and decision making test was used to stratify participants as skilled 'high-performing' and skilled 'low-performing'. A third group classified as recreational performers was used as a control group. Participation history data were gathered using retrospective recall questionnaires. No between-group differences were expected for milestones achieved, such as start age in soccer (which was predicted to be around 5 years of age), supervised training in soccer, and age at which participants started playing in an organised league (Helsen, Starkes, & Hodges, 1998; Ward, Hodges, Starkes, & Williams, 2007; Ford et al., 2009). It was expected that the average hours per year in soccer-specific practice activities during adolescence (i.e., 13-18 years of age) would be a predictor of superior anticipation and decision making performance across participants (e.g., Ford et al., 2010a; Weissensteiner et al., 2008) and would differentiate skill groups (i.e., greater amounts of this activity will co-occur with higher scores on the test as indicated by group membership). It was further expected, based on the findings of Ford et al. (2009) that a greater number of hours in soccer-specific play activities during childhood (i.e., 6-12 years of age) would be a predictor of test performance and would differentiate the skill groups. Moreover, it is likely that hours accumulated in total soccer activity by 18 years of age will differentiate skill groups, as per Ford et al. (2010a). No other soccer activities were expected to predict this ability or to differentiate skill groups. It was assumed that the development of anticipation and decision making in soccer is mainly a result of participation in the primary sport, rather than engagement in other sports per se (e.g., Berry et al., 2008), due to the low number of other sports engaged in by soccer players during their development (e.g., Ford et al., 2009; Ward et al., 2007).

Methods

Participants

A total of 48 skilled, male outfield soccer players (*M* age = 20.7 years, *SD* = 2.4) participated. Players were recruited from a range of different semi-professional soccer clubs in the United Kingdom. A second control group comprised of 16 amateur and recreational-level players (*M* age = 22.1 years, *SD* = 2.8). Participants provided informed consent and the research procedures were conducted according to the ethical guidelines of the lead institution.

Apparatus

Perceptual-cognitive test. Participants were presented with life-size video sequences involving dynamic, 11 versus 11 soccer situations filmed and viewed from a player's perspective (for a detail description on the creation of the test film, see Chapter 2, pp. 29-30). The perceptual-cognitive soccer simulation test comprised of four practice and 20 test trials. The action sequences lasted approximately 5 s, with each one being occluded at a key moment in the action (e.g., player in possession of the ball about to make an attacking pass, shoot at goal, or maintain possession of the ball by dribbling forward). Each video clip ended with a white screen in order to prevent the participants from receiving any information from the last frame when the clips were occluded.

Questionnaire. The Participant History Questionnaire (PHQ) first used by Ford et al. (2010) was used to trace the developmental activities undertaken by players. The questionnaire comprised of three different sections. The first section recorded information on soccer-specific milestones. These milestones were the age at which participants first took part in soccer (e.g., kicking around), supervised training in soccer with an adult, organised soccer league, and semi-professional soccer. The second section of the questionnaire elicited information on engagement in soccer-related activities. Three soccer activities were examined, namely, competition, practice and play. Competition referred to the time spent playing organised competitive matches against another team in which the intent is to win (e.g., league games). Practice referred to soccer activity undertaken alone or in a group under the supervision of coaches or adults in which the intent is to improve performance (e.g., practice with the team). Play activities referred to play-type games with rules supervised by participants themselves in which the intent is enjoyment (e.g., game of soccer in park with friends). Participants provided the number of hours per week and the number of months per year spent in each of the soccer activities in each year of participation in the sport. Players were required to provide the number of weeks from each year they were injured and unable to participate in any soccer-related activity. This information was reported retrospectively for the present season/year, then working backwards in two-year intervals until the age they first started playing soccer.

The final section of the questionnaire recorded information on engagement in other sporting activities. A list of sports was provided and participants were required to indicate which ones they had taken part in on a regular basis (i.e., a minimum period of at least 3 months) outside of school physical education classes during their development. The age at which they started and finished (unless they were still involved in the sport) playing each sport was recorded. Space was provided to include information on any sports they had participated in that were not on the list.

Procedure

The procedures were explained to the participants prior to commencing the tasks. Video clips were back projected onto a 2.7 m (h) x 3.6 m (w) widescreen (Draper Cinefold, Spiceland, IN, USA) using a 3LCD video projection system (Hitachi ED-A101, Yokohama, Japan). Participants stood 2.5m away from the screen affording them a typical viewing angle of around 28° to 35° degrees in the vertical and horizontal planes, respectively. Three different starting positions were marked on the floor (i.e., one to the right, one to the left, and one central to the screen) to ensure that the participant began each particular clip accurately positioned relative to the on-screen action (as determined by the panel of coaches). Participants were free to interact and move with the action sequence as they would normally do when playing in a 'real-world' soccer match situation. At the end of each video clip, participants were required to confirm 'What the player in possession was going to do?' and 'What decision the participant themselves made or were about to make at the moment of video occlusion?' The movements of participants were recorded using a digital video camera (Canon LEGRIA FS200, Tokyo, Japan) positioned 3m behind the participant and linked to a monitor (Philips 15PF5120, Eindhoven, Netherlands) placed on the experimenter's desk. The experimenter's desk was positioned directly behind the participant's start position, 6 m from the screen. Participants completed four warm-up trials for pre-test familiarisation. The total duration of each individual test session was approximately 30 min.

Following completion of the test, participants completed the PHQ in order to elicit information about their practice history profiles. Questionnaires were completed individually, under supervision and at a desk adjacent to the test setting. The experimenter provided verbal instructions on how to fill in the questionnaire and was available at all times to answer any queries related to the interpretation and completion of the questionnaire. Participants took approximately 45 min to complete the questionnaire.

Reliability

The test-retest method was employed on a sample of five randomly selected participants to assess the reliability of retrospective responses to the questionnaire in terms of hours in soccer activities. The retest involved the PHQ being administrated to the sub-sample of participants three months after the first test. Two statistical methods were applied to assess measurement error between test-retest. First, the relative reliability, which corresponds to the level of association between the two tests, was checked using an intraclass correlation (Atkinson & Nevill, 1998; Thomas et al., 2005). Second, the limits of agreement method was used to examine the absolute reliability, which corresponds to the level of agreement between the two tests (Atkinson & Nevill, 1998; Bland & Altman, 2007). A large intraclass correlation coefficient was reported for the hours per week spent in each of the three different soccer activities, $R(104) = .90$. The limits of agreement were 0.27 ± 1.40 hr, $p > .05$, confirming that there were no significant systematic errors between the test-retest.

Data Analysis

The main dependent measures were the response accuracy scores for anticipation and decision making, respectively. Anticipation accuracy was defined as whether or not the participant correctly selected the next action of the player in possession of the ball at the moment of video occlusion (e.g., passed to a teammate and which teammate, shot at goal, or continued dribbling the ball). For the decision making measure, a panel of three UEFA qualified soccer coaches independently selected the most appropriate decision for a participant to execute in response to the situation at the time of video occlusion on each trial. The accuracy was then defined as whether or not the participant decided on the action selected by the coaches as most appropriate for that trial. The inter-observer agreement between coach selections was 92%. The anticipation and decision making accuracy were calculated as the mean number of trials (in %) in which the participant made the correct response. The performance scores for both response accuracies were averaged into a combined test score for each participant.

Participation history profile data were analysed for two age periods (i) 6-12 years (i.e., childhood) and (ii) 13-18 years of age (i.e., adolescence) to approximately match the developmental stages outlined by Côté (1999). The accumulated hours in soccer activity for each year between 6 and 18 years of age were calculated by multiplying hours reported per week by weeks per year, minus weeks per year players reported as being injured and unable to participate in soccer activities. The number of weeks per year was based on a 40-week season. As per Ford and Williams (2008), linear interpolation was used to calculate missing data for each single year within each 2-year interval where no data were collected. The average hours per year in the three soccer activities across age categories were calculated by summing accumulated hours in each activity within a stage and then dividing by the number of years in that stage. The average hours per year in each of the three soccer activities as a function of the two age stages were used as the dependent variable in the subsequent inferential analyses.

First, a hierarchical multiple regression analysis was conducted on the average hours per year in the soccer activities as a function of stage for the 48 skilled participants only to determine which were most predictive of performance on the perceptual-cognitive test. The variables for soccer practice activity for adolescence and childhood were given priority at Step 1 and 2 respectively as it was hypothesised from existing literature that practice activity in the primary sport would co-occur and possibly contribute to the acquisition of anticipation and decision making (e.g., Ford et al., 2010a; Weissensteiner et al., 2008). At Step 3, soccer-specific play activity for childhood was entered as it had been predicted that the co-occurrence and possible contribution of this variable may account for the development of these two abilities (e.g., Ford et al., 2009). No a-priori hypotheses were formed regarding the remaining activities and so these variables were entered simultaneously in Step 4.

Second, two groups were created from the total sample of skilled players based on their combined scores from the perceptual-cognitive test. The top 16 ranked skilled players were classified as skilled high-performing, whereas players ranked in the bottom 16 of this group were classified as skilled low-performing. Players ranked in the middle 16 skilled participants were removed from the analysis. A third group (n =16) classified as recreational was used as a control group. The combined scores from the perceptual-cognitive test were analysed using one-way analysis of variance (ANOVA) in which Group (skilled high-performing, skilled low-performing and recreational) was the between-participant factor. In this second analysis, the average hours per year in each of the three soccer activities were subjected to 3 Group (skilled high-performing, skilled low-performing and recreational) x 3 Activities (competition, practice and play) ANOVAs with repeated measures on the last factor. The data for childhood and adolescence periods were analysed separately.

The milestones of start age in soccer, start age in supervised training with an adult, start age in organised soccer league (i.e., competition), start age in elite training programme of a professional club (i.e., soccer school of excellence or academy), and start age in semi-professional soccer were analysed separately using one-way ANOVAs between the skilled high-performing, skilled low-performing and recreational groups. The number of other sports were analysed using separate one-way ANOVAs for each age period (i.e., childhood and adolescence) between groups (skilled high-performing, skilled low-performing and recreational). Any violations of sphericity were corrected using Greenhouse-Geisser and Huynh-Feldt procedures. The effect sizes were calculated using partial eta squared (η_p^2) values and Cohen's *d* as appropriate. Any significant main and interaction effects were followed up using Bonferroni-corrected pairwise comparisons and Tukey's HSD post hoc tests, respectively. The alpha level required for significance for all tests was set at $p < .05$.

Results

Skilled Group

The response accuracy score for the perceptual-cognitive test for the 48 skilled players was 69.9% (SD = 8.8).They commenced participation in soccer aged 5.4 years (SD = 1.2). Players first took part in supervised training in soccer with an adult at age 8.0 years (SD = 2.2). All skilled players started playing in an organised soccer league at an average age of 8.9 years (SD = 2.1). Twenty eight out of forty eight skilled players played in the elite training programme of a professional club from a start age of 12.4 years (*SD* = 2.9). All players started in adult semi-professional soccer at the age of 17.6 years (*SD* = 1.3).

The hierarchical multiple regression analysis in which the perceptual-cognitive test score was the criterion variable and the three soccer activities (competition, practice, and play) for (i) 6-12 years and (ii) 13-18 years of age were the predictor variables produced significant equations for the first and third steps of the analysis (see Table 5.1). The overall regression model accounted for 39.0% of the variance in perceptual-cognitive skill, $R^2 = .39$, $F(6, 41) = 4.36$, $p = .002$. In Step 1, the average hours per year in practice in soccer for 13 to 18 years of age alone explained 13.2% of the variance for perceptual-cognitive performance accuracy, $F_{change}(1, 46) = 6.96$, $p = .011$. When average hours per year in soccer-specific practice for 6-12 years of age was entered in the second step of the analysis, it did not significantly improve prediction accuracy, $F_{change}(1, 45) = 0.15$, $p = .702$. In Step 3, inclusion of average hours per year in soccer play activity for childhood increased explained variance by a further 21.8%, $F_{change}(1, 44) = 14.80$, $p < .001$. In the final step, when the remaining soccer activities (i.e., competition during childhood, play during adolescence, and competition during adolescence) were entered they did not produce any significant change on the overall model's variance, $F_{change}(3, 41) = 0.84$, $p = .480$.

A total of 42 out of the 48 skilled participants engaged in an average of 2.8 other sports (*SD* = 1.7). The start age in other sports was 11.1 years of age (*SD* = 2.3), which coincided with the age at which participants entered secondary school. The skilled participants engaged in altogether 22 different sports. The most popular sports were athletics (*n* = 15 players), cricket (*n* = 14 players) and basketball (*n* = 14 players), swimming (n = 12 players), tennis (n = 10 players), golf and badminton (n = 11 players each).

Table 5.1

Summary of Hierarchical Regression Analysis for Soccer Activity Variables Predicting Perceptual-Cognitive Skill

Predictor variables	*B*	*SE B*	β
Step 1			
Constant	61.03	3.59	
Practice (13-18 years)	0.06	0.02	.36*
Step 2			
Constant	61.52	3.84	
Practice (13-18 years)	0.06	0.02	.38*
Practice (6-12 years)	-0.02	0.04	-.06
Step 3			
Constant	53.91	3.90	
Practice (13-18 years)	0.04	0.02	.23
Practice (6-12 years)	-0.03	0.03	-.12
Play (6-12 years)	0.05	0.01	.50***
Step 4			
Constant	52.56	5.08	
Practice (13-18 years)	0.04	0.02	.25
Practice (6-12 years)	-0.08	0.05	-.31
Play (6-12 years)	0.05	0.01	.54**
Play (13-18 years)	0.00	0.02	.02
Competition (13-18 years)	-0.01	0.04	-.04
Competition (6-12 years)	0.11	0.07	.27

Note. R^2 = .13 for Step 1; ΔR^2 = .00 for Step 2; ΔR^2 = .22 for Step 3; ΔR^2 = .04 for Step 4.
*p < .05, ** p < .01, and ***p < .001.

Skilled High- versus Low-Performing versus Recreational Groups

Perceptual-cognitive performance. There was a significant difference between groups for response accuracy on the perceptual-cognitive test, $F(2, 45) = 240.93$, $p < .001$, $\eta_p^2 = .92$. The skilled high-performing players ($M = 80.0\%$, $SD = 3.7$) had a significantly higher score on the perceptual-cognitive test compared with the skilled low-performing ($M = 60.3\%$, $SD = 4.6$) and recreational groups ($M = 42.8\%$, $SD = 5.8$). Also, the skilled low-performing scored significantly higher than the recreational group.

Milestones. No differences were found in the chronological age of the skilled high-performing ($M = 20.9$ years, $SD = 3.1$), skilled low-performing ($M = 20.5$ years, $SD = 2.0$) and recreational groups ($M = 22.1$ years, $SD = 2.8$), $F(2, 45) = 1.72$, $p = .19$, $\eta_p^2 = .07$. The start age in soccer did not differentiate the skilled high-performing ($M = 5.2$ years, $SD = 1.3$), skilled low-performing ($M = 5.6$ years, $SD = 1.1$) and recreational groups ($M = 5.5$ years, $SD = 1.2$), $F(2, 45) = 0.61$, $p = .55$, $\eta_p^2 = .03$. The age at which participants first took part in supervised training in soccer with an adult also did not differentiate the skilled high-performing ($M = 7.5$ years, $SD = 1.9$) from the skilled low-performing ($M = 8.0$ years, $SD = 2.2$) and recreational players ($M = 7.9$ years, $SD = 1.9$), $F(2, 39) = 0.40$, $p = .68$, $\eta_p^2 = .02$. The age at which the participants started playing in an organised soccer league was not different between the skilled high-performing ($M = 8.5$ years, $SD = 2.0$), the skilled low-performing ($M = 8.9$ years, $SD = 1.9$) and recreational groups ($M = 9.3$ years, $SD = 1.3$), $F(2, 37) = 0.49$, $p = .62$, $\eta_p^2 = .03$. Also, there were no differences between the skilled high-performing ($n = 11$; $M = 12.2$ years, $SD = 2.6$) and low-performing groups ($n = 8$; $M = 11.0$ years, $SD = 3.9$) for the age they first engaged in an elite training programme at a professional club, $F(1, 17) = 6.33$, $p = .44$, $\eta_p^2 = .04$. Finally, there were no differences between the skilled high- (M = 17.6 years, SD = 1.7) and low-performing groups (M = 17.6 years, SD = 1.2) for the age they had started playing soccer at an adult semi-professional level, $F(1, 30) = 0.02$, $p = .90$, $\eta_p^2 = .00$. Recreational players did not reach the semi-professional milestone, but eight of the recreational group players took part in soccer at an amateur level at the age of 17.3 years (SD = 0.7).

Soccer activity. Figure 5.1 presents the average hours per year between 6 and 18 years of age in the three soccer activities for the skilled high-performing, skilled low-performing, and recreational groups. The statistical results for average hours per year in soccer activity in childhood are presented in Table 5.2. The average hours per year in soccer activity during childhood were significantly greater for the skilled high-performing (M = 449.2 hr/year, SD = 146.5) players compared with the other two groups. Moreover, the average hours per year in soccer activity for skilled low-performing players (M = 317.4 hr/year, SD = 69.6) was significantly higher when compared to the recreational players (M = 190.1 hr/year, SD = 65.1). The average hours per year in soccer play activities (M = 229.7 hr/year, SD = 106.1) during this period were greater than those in the other two types of activity. The skilled high-performing group (M = 339.0 hr/year, SD = 125.4) spent significantly more average hours per year in soccer-specific play activity in comparison with the other two groups. The skilled low-performing group (M = 207.6 hr/year, SD = 50.6) also engaged in a greater number of average hours per year in soccer-specific play activities compared with the recreational players (M = 142.4 hr/year, SD = 39.5). The average hours per year in practice activity (M = 54.0 hr/year, SD = 35.7) were also greater than those in competition (M = 35.3 hr/year, SD = 23.7) (see Figure 5.1).

The statistical results for average hours per year in soccer activity during adolescence are displayed in Table 5.2. There were no significant differences for the average hours per year in soccer activity during this period between the skilled high-performing (M = 467.1 hr/year, SD = 92.3) and skilled low-performing (M = 390.3 hr/year, SD = 105.2) groups. However, these two groups engaged in a greater number of average hours per year in soccer when compared with the recreational group (M = 223.3 hr/year, SD = 113.7). The average hours per year in soccer-specific play activity (M = 165.4 hr/year, SD = 65.1) during this period were greater compared to the other two activity types. The average hours per year in practice activity (M =121.0 hr/year, SD = 69.6) were greater than those in competition (M = 73.8 hr/year, SD = 41.8). A significantly greater number of average hours per year were spent in both soccer practice and competition activities by both skilled high-performing (M = 178.1 hr/year, SD = 54.6 and M = 94.2 hr/year, SD = 31.2, respectively) and skilled low-performing groups (M = 137.4 hr/year, SD = 44.4 and M = 90.7 hr/year, SD = 31.2) when compared with the recreational players (M = 47.7 hr/year, SD = 48.2 and M = 36.6 hr/year, SD = 37.7). Moreover, the skilled high-performing group (M = 194.8 hr/year, SD = 57.6) engaged in more hours per year during adolescence in soccer-specific play activity in comparison with the recreational group (M = 139.1 hr/year, SD = 52.3) (see Figure 5.1). A one-way ANOVA revealed that by 18 years of age, the skilled high-performing players (M = 5946.9 hr, SD = 1469.7) had accumulated more total hours in soccer activity compared to their skilled low-performing counterparts (M = 4563.7 hr, SD = 768.9), with both groups accumulating more hours compared to the recreational group (M = 2670.4 hr, SD = 1075.0), $F(1, 45) = 33.24, p < .001, \eta_p^2 = .60$.

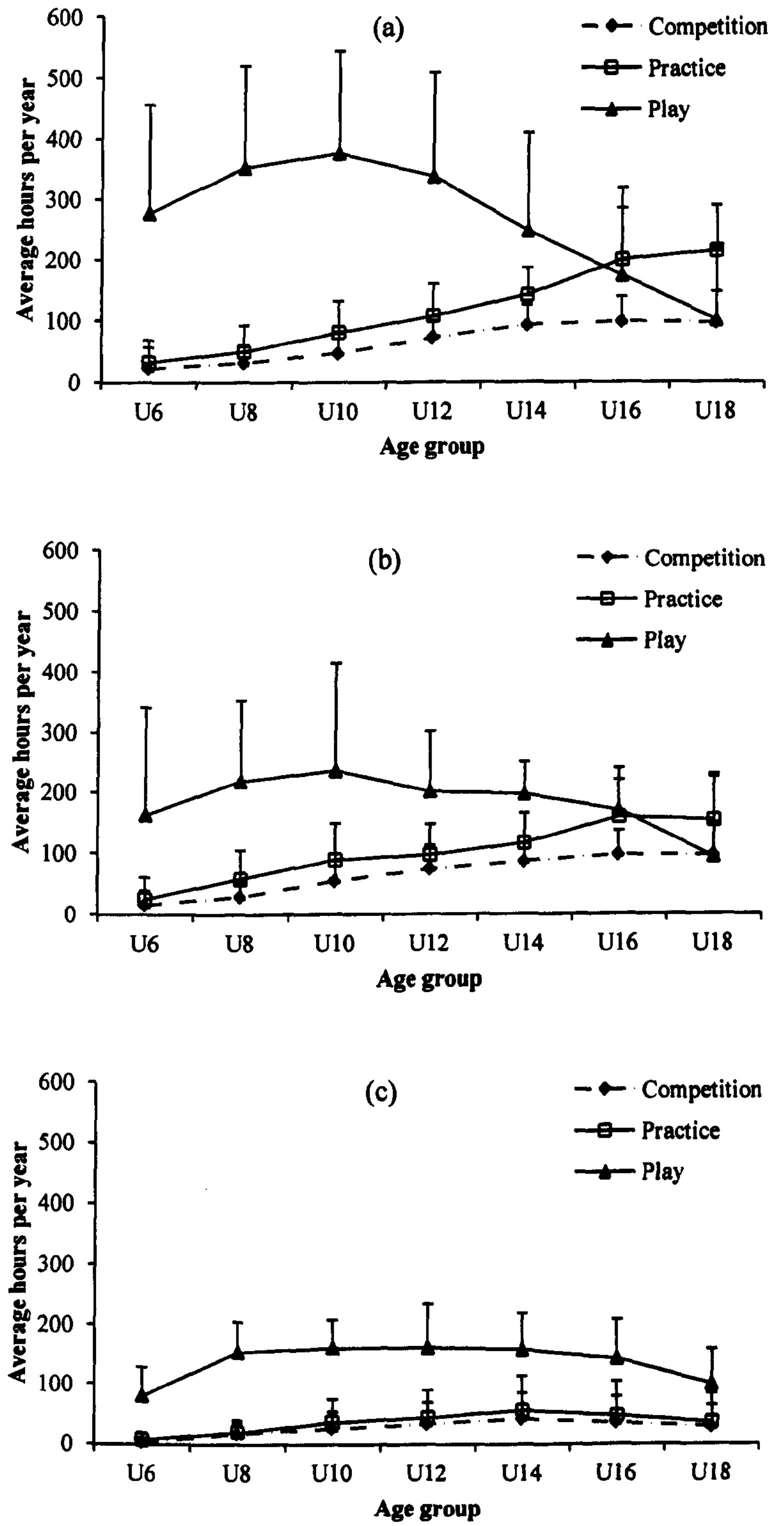


Figure 5.1. Mean (*SD*) average hours per year in the three soccer activities for (a) skilled high-performing, (b) skilled low-performing and (c) recreational players.

Table 5.2

Results of Separate ANOVAs on Average Hours per Year in Soccer Activity

Variable and comparison	*MS*	*MSE*	*F*	Effect size η_p^2
Average hours per year (6-12 years)				
Group	89,529.75	3,392.72	26.39***	.54
Activity	983,579.03	4,331.34	227.08***	.84
Group x Activity	73,090.28	4,331.34	16.88***	.43
Average hours per year (13-18 years)				
Group	82,855.89	3,610.87	22.95***	.51
Activity	107,347.69	2,274.30	47.20***	.51
Group x Activity	9,391.26	2,274.30	4.13**	.16

Note. $df = (2, 45)$.
*$p < .05$, ** $p < .01$, and ***$p < .001$.

Other sports activity. Start age in other sports did not differentiate the skilled high-performing (M = 11.5 years of age, SD = 2.3), skilled low-performing (M = 10.8 years of age, SD = 1.7) and recreational groups (M = 11.1 years of age, SD = 2.1), $F(2, 43) = 0.47$, $p = .63$, $\eta_p^2 = .02$. The number of other sports engaged in during childhood did not differentiate the skilled high-performing (M = 2.1 sports, SD = 1.8), skilled low-performing (M = 2.2 sports, SD = 1.7) and recreational groups (M = 2.2 sports, SD = 1.2), $F(2, 45) = 0.03$, $p = .97$, $\eta_p^2 = .00$. The number of other sports during adolescence did not differentiate the skilled high-performing (M = 2.7 sports, SD = 1.4), skilled low-performing (M = 2.4 sports, SD = 1.6) and recreational groups (M = 2.6 sports, SD = 1.3), $F(2, 45) = 0.20$, $p = .82$, $\eta_p^2 = .01$. The most popular other sports for the skilled high-performing players were athletics and basketball (n = 7 players), whereas for the skilled low-performing players these were swimming ($n = 5$), athletics, badminton and basketball ($n = 4$ players each). For the recreational group, judo ($n = 6$) and cricket ($n = 5$) were the most popular other sports.

Discussion

This research examined whether soccer players who were classified as high- or low-performing based on their scores on tests that evaluated their ability to anticipate and make decisions could be differentiated based on the type and amount of activities that they had engaged in during development. Participation history profiles were collected using a retrospective recall questionnaire. No between-group differences were expected for the start age in soccer, which was predicted based on previous findings to be around 5 years of age (e.g., Ford et al., 2009; Helsen et al., 1998; Ward et al., 2007). It was expected, based on previous data (e.g., Ford et al., 2009), that hours spent in soccer-specific play activity during childhood would be greater for the high-performing group compared to the other two groups and would be a predictor of performance on the anticipation and decision making test. As per previous research (e.g., Ford et al., 2010a; Weissensteiner et al., 2008), participants in the high-performing group were expected to have engaged in more hours of soccer-specific practice activity during adolescence compared to the other two groups; this activity was expected to be a predictor of anticipation and decision making ability. The predicted activity differences were expected to lead to a between-group difference in hours accumulated in all soccer activity by 18 years of age. No between-group differences were expected in other soccer activities or for the number of other sports engaged in during the two stages of development.

As predicted, there were no between-group differences for milestones achieved, such as the start age in soccer ($M = 5$ years), age at which players first took part in supervised training in soccer with an adult ($M = 8$ years) and, age at which they started playing in an organised soccer league ($M = 9$ years). The age at which these milestones were achieved did not differ to those reported in previous research with soccer players (Ford et al., 2009; Helsen et al., 1998; Ward et al., 2007). Also, as predicted, the average hours per year in soccer-specific play activity during childhood explained a moderate amount (21.8%) of the variance in test scores and differentiated skill groups. These findings provide support for Ford et al. (2009) who showed that the average hours per year during childhood in soccer play activity was the only activity to differentiate elite youth players who progressed to professional status in adulthood from those who engaged in less of that activity and did not progress. The skilled high-performing group were engaging in around 339 hr/year of this activity during childhood, which is comparable with the 338 hr/year (or 7 hr/week across a 50-week year) reported by Ford et al. (2009) for elite youth players in England who progressed to professional status. The skilled low-performing group averaged more hours per year in soccer-specific play activity when compared with the recreational group. The skilled low-performing group were engaging in 208 hr/year of this activity during childhood, which is slightly greater than the 148 hr/year reported by Ford et al. (2009) for elite youth players in England who did not progress to professional status. Moreover, recreational players in the current study engaged in this activity for 142 hr/year compared to the 158 hr/year reported by Ford et al. (2009). The co-occurrence of greater amounts of soccer play activity during childhood within successively higher skill groups suggests that this activity may contribute to anticipation and decision making ability.

In line with the initial predictions, during adolescence, the average hours per year in soccer practice activity explained some of the variance (13.2%) in anticipation and decision making ability. This later observation partly supports findings reported by Weissensteiner et al. (2008) who showed that hours accumulated in formal activities in cricket was the main contributor to the variance (11-13%) in performance on an anticipation test involving cricket. Weissensteiner and colleagues (2008) did not separate their analysis into developmental age stages and their formal cricket activities included both practice and competition. Although no activity differences were apparent between skilled high- and low-performing players, both groups took part in significantly more hours per year in soccer-specific practice and competition activities during adolescence compared to their recreational counterparts. These results support those reported by Ford et al. (2010a), Ward et al. (2007) and Weissensteiner et al. (2008), with skilled groups accumulating significantly more hours per year in structured soccer activities during adolescence. The skilled high- and low-performing groups were engaging in around 4 hr/week of soccer practice activity during adolescence, which is lower than the 5 to 9 hr/week reported for international soccer players during adolescence (Helsen et al., 1998), although players in the latter study attained a higher level of participation. No other soccer activities in either stage contributed to the test scores. However, the between-group differences observed in the different types of soccer activity led to the hours accumulated in all soccer activity by 18 years of age differentiating groups in the predicted manner. It is possible that simply accumulating more hours in the sport may have led to superior performance on the test. In previous research, where between-group differences are observed in a specific type of soccer activity, this has also led to differences in the hours accumulated in all soccer activity (e.g., Ford et al., 2010a).

The three skill groups were not predicted to be differentiated based on their engagement in other sports, which was expected to be low across childhood and adolescence (e.g., Ward et al., 2007). Players participated in a mean number of two other sports during childhood, which they mainly started participating in at secondary school age (*M* start age = 11 years). This finding contradicts previous research used to support the 'early diversification' pathway proposed by Côté (1999). For example, Canadian ice hockey players engaged in six other sports (Soberlak & Côté, 2003), while Australian rules football players showed a strong relationship between high amounts of other sport activity and better 'decision making' in the primary sport (Berry et al., 2008). One speculation regarding this finding is that the skilled high-performing group were following the 'early engagement' pathway proposed by Ford et al. (2009), rather than the 'early diversification' pathway. This pathway is defined by athletes participating mainly in deliberate play in the primary sport during childhood, engaging in limited or no other sports activity, participating in some deliberate practice in the primary sport during childhood, and late or delayed (i.e., 13 to 15 years of age) engagement in large amounts of deliberate practice in the primary sport. It is hypothesised that engagement in sport-specific play during childhood as outlined in the 'early engagement' pathway is a key part of the development of anticipation and decision making in soccer. The proposal is that during play activity there may be significant opportunities for players to engage in situations that require anticipation and decision making leading to specific adaptations in these abilities that transfer to competition and match-play performance.

The use of retrospective recall data has some limitations, such as the potential for memory/recall bias by participants (Hodges et al., 2007). In future, researchers should attempt to better identify the specific amount and type of practice that players engage in throughout the various stages of development, perhaps by conducting a more sophisticated longitudinal analysis of these activities in conjunction with monitoring changes in specific performance attributes over time (Ericsson, 2003a). In addition, further research is needed toward detailed causal accounts for the development of performance attributes, such as anticipation and decision making. Traditional experimental designs with controlled training interventions may be used for this purpose in an effort to explore causal links between engagement in certain types of practice activities and specific changes/adaptations to different aspects of performance (e.g., anticipation and decision making).

In summary, skilled players were categorised into high- or low-performing groups based on their scores on a test of anticipation and decision making. An examination was made to whether these groups could be differentiated in regard to the amount and type of activities in which they had participated during their development. The average hours per year in soccer-specific play activity during childhood was the strongest predictor of performance on the perceptual-cognitive test and differentiated the skill groups. It was hypothesised that soccer-specific play activity during childhood provides the conditions for players to engage in anticipation and decision making leading to lasting adaptations and improvements in these abilities. Soccer-specific practice activity during adolescence was also a contributing factor to the variance in anticipation and decision making scores across participants, which supports previous work in cricket (Ford et al., 2010a, Weissensteiner et al., 2008). No differences across groups were reported for some of the key milestones achieved as well as the number of other sports engaged in during development, contradicting the 'early diversification' pathway (Côté, 1999).

Chapter 6

Epilogue

This chapter will provide a detailed synthesis of the work presented in the thesis and outline its implications for both theory and practice. The limitations of the work are discussed, as well as potential avenues for future research in the area of expertise and expert performance.

Aims of the Thesis

The aims of the present thesis were to examine how expert players anticipate and make decisions in soccer and how these abilities are acquired through prolonged engagement in the domain. The expert performance approach (Ericsson & Smith, 1991) was applied as a guiding framework for this research programme. Although a number of researchers have successfully examined perceptual-cognitive expertise in dynamic, team ball sport environments such as soccer, there are still an array of key shortcomings in the literature that need to be addressed. Particularly, a reductionist approach has typically been employed with researchers focusing their efforts on developing paradigms that isolate single perceptual and/or cognitive components or skills for systematic investigation.

In response to some of the limitations in previous research on expertise, an effort was made to provide a more holistic and inclusive representation of perceptual-cognitive expertise in the sport of soccer. In particular, an attempt was made to develop a representative simulation of complex and continuous open-play situations in soccer, including performance measures of anticipation and decision making. Moreover, the thesis examined the processes of cognition that mediate perception, anticipation, and decision making. For the first time in the literature, an attempt was made to determine how the different perceptual-cognitive skills (e.g., postural cues, pattern recognition, and situational probabilities) interact with each other in a dynamic and evolving manner during anticipation and decision making.

Finally, the thesis aimed to identify the specific types of activities that lead to the acquisition and development of anticipation and decision making, as well as their mediating mechanisms.

The first stage of the expert performance approach proposes that the characteristics of expertise should be objectively examined under standardised conditions via the design of representative laboratory (or field) -based tasks. Therefore, the aim in Chapter 2 was to develop a valid and reliable representative simulation task that could effectively capture anticipation and decision making in soccer, as well as their component skills, under controlled conditions in the laboratory. The second stage of the expert performance approach proposes that process-tracing measures are employed to determine the mediating mechanisms that account for superior performance. Chapters 3 and 4 identified and examined the mediating processes underlying superior anticipation and decision making on the representative task developed in Chapter 2. A combination of process measures, comprising of eye-movement recording and verbal protocol analysis, was employed across in an effort to provide a detailed and comprehensive representation of the processes underpinning perceptual-cognitive expertise. Moreover, a novel approach that incorporated the manipulation of task-situation scenarios (i.e., ball distance relative to the participant/player) was employed in Chapter 4. The aim of this approach was to examine for the first time how the relative importance of the different perceptual-cognitive skills vary and interact with each other as a function of the unique constraints imposed by the performance setting.

In the third and final stage of the expert performance approach, efforts are devoted to determine how experts acquire the component skills needed to demonstrate reliably superior performance on a task. Chapter 5 examined whether skilled soccer players categorised as either high- or low-performing, based on their performance on the film-based test of anticipation and decision making, could be differentiated based on the amount and/or type of activity(ies) undertaken over the course of their skill development. Overall, the thesis aimed to progress understanding of the factors that contribute to exceptional performance and its development, which may be used to develop more refined theoretical models of expertise and skill acquisition.

Summary of Key Findings

Chapter 2 attempted to develop a representative laboratory-based simulation that could effectively capture the essence of perceptual-cognitive expertise in soccer. In Experiment 1, the cognitive thought processes of two groups of skilled players were compared during their performance on the simulation task: a non-movement and a movement response group. The movement response group verbalised a larger number of cognitive statements with a higher proportion related to the assessment and prediction of future options, and the planning/selection of an appropriate action response when compared with the non-movement group. The lack of a movement response for the non-movement group appears to have altered to some degree what could be considered their normal performance and processing strategies. In Experiment 2, measures of performance (i.e., anticipation and decision making) were determined across a group of skilled and less skilled participants in an attempt to validate the simulation task with the movement response (from Experiment 1). Skilled participants were significantly more accurate at anticipation and decision making compared with the less skilled counterparts. Findings confirmed the construct validity of the simulation task with a movement response.

In Chapter 3, a multidimensional analysis of the mediating mechanisms underlying superior anticipation and decision making, including eye-movement recording (Experiment 3), retrospective verbal reports of thinking (Experiment 4), and outcome performance measures, was employed. Skilled players were more accurate than less skilled counterparts at anticipating the actions of opponents and in deciding on an appropriate course of action. In Experiment 3, skilled players employed a visual search strategy involving more fixations of shorter duration towards more disparate and informative locations (e.g., opponent players and areas of free space) in the display compared to their less skilled peers. Additionally, skilled participants alternated their gaze more frequently between players in possession of the ball/ball itself and any other area of the scene in comparison with the less skilled participants. This search sequence or pattern is presumed to be extremely valuable, primarily during highly dynamic situations, since it enhances the player's awareness of teammates and opponents' positions and movements, and potential areas of free space that may be exploited or exposed. In Experiment 4, skilled participants generated a greater number of verbal report statements with a higher proportion of evaluation, prediction, and planning statements than the less skilled participants. The skilled players' statement types suggest that they employed more complex domain-specific memory representations when compared with less skilled players, allowing the current events and potential outcomes to be considered and assessed, rather than merely monitored in their present state.

In Chapter 4, a novel manipulation of the situational task constraints of the ball distance relative to the player/participant (i.e., far vs. near task conditions) was employed. The main purpose of the experiment was to examine whether and how the different perceptual-cognitive skills interact with each other in a dynamic manner during performance to facilitate anticipation and decision making. The same process-tracing measures applied in Chapter 3 were recorded in this experiment. In Experiment 5, skilled soccer players employed different visual search strategies when viewing the whole field of play (i.e., far task) compared with more microstates of the game (i.e., near task). When the ball was far away from the player/participant, an extensive search pattern involving more fixations of shorter duration was employed. This strategy potentially makes players more aware of the positions and movements of players on and off the ball. On the other hand, when the ball was closer, they employed lower search rates, generally fixating gaze centrally on the player in possession of the ball and, perhaps, relying on peripheral vision to monitor the players' movements. In contrast, less skilled players tended to fixate the ball in both conditions, with the only difference being in the number of fixations across the two tasks.

In Experiment 6, verbal protocol analysis showed that skilled participants generated significantly more predictive and planning statements when interacting with the near task compared with the far task clips. No differences were revealed for less skilled participants in the type of verbal statements made across task conditions. It may be that the more attention demanding and temporal-constrained setting of the near task led to skilled players directing greater attention on predictive contextual information of potential future events and the planning of a decisional response to a possible outcome situation. Such findings illustrate the plasticity of skilled players' underlying cognitive processes to the unique constraints of the situational task.

Further analysis of the verbal report data highlighted the existence of a continuous and highly dynamic interaction between the different perceptual-cognitive skills during performance. The relative importance of advance cue utilisation, pattern recognition, and situational probabilities varied considerably as a function of the two situational task constraints. Accordingly, in the far task, skilled participants in particular generated more statements related to pattern recognition (i.e., the relational information between players), whereas in the near task, they made more statements about the postural cues of opponents/teammates, followed by situational probabilities (i.e., expectations about event outcomes). The data may be interpreted as showing that superior perceptual-cognitive expertise and its underlying processes in soccer are underpinned by a series of complex task-specific knowledge representations and skills. These representations guide input and retrieval of relevant information from the visual scenery and memory in a dynamic and integrated manner.

The final study (Chapter 5) was undertaken to determine how experts acquired reliably superior anticipation and decision making performance. The aim was to examine whether soccer players at varying levels of perceptual-cognitive expertise could be differentiated based on their engagement in various types and amounts of activity during their development. Three skill groups separated by their anticipation and decision making accuracy scores obtained in the soccer simulation test took part in the study: skilled high-performing, skilled low-performing, and recreational players. The participation history profiles of the players were recorded using retrospective recall questionnaires. The average hours accumulated per year in soccer-specific play activity during childhood (i.e., 6-12 years of age) was the strongest predictor of performance on the perceptual-cognitive test and differentiated the skill groups. Soccer-specific practice activity during adolescence (i.e., 13-18 years of age) was also a predictor, albeit its impact was relatively modest. It appears that engagement in greater amounts of sport-specific play during childhood provides an excellent environment for fostering the mechanisms that promote the development and acquisition of anticipation and decision making ability in soccer. No differences across groups were reported for key milestones achieved (e.g., start age in soccer) or the number of other sports engaged in during development, contradicting the early diversification pathway.

The previous section has identified and summarised the key findings from Chapters 2, 3, 4, and 5. The subsequent section will look at the implications of these findings for theory and practice.

Implications for Theory and Practice

A number of factors deemed important for the study, understanding, and development of expert performance in soccer emerged in this thesis. Chapter 2 highlighted the challenges facing researchers attempting to design representative laboratory (or field) tasks of open-play team ball sport situations due to the particular complex dynamics and fast altering nature of the competitive setting. Findings showed that the underlying cognitive processes mediating anticipation and decision making differed between task conditions higher or lower in fidelity. More advanced processing strategies were employed in more representative movement response situations in comparison with non-movement response conditions. The lack of movement response in the non-movement condition led the skilled participants to use different processes to that which they normally use to solve a particular problem, which may possibly be counterintuitive to their capacity to produce superior performance (Abernethy et al., 1993). The design of higher-fidelity simulations is likely to enhance measurement sensitivity, which would help identify the key elements accounting for superior performance on a task, as well as better distinguishing players in terms of their skill level (Dicks et al., 2009; Williams & Ericsson, 2005).

The findings presented in Chapters 3 and 4 showed that skilled soccer players employed quantitatively different visual search behaviours compared to lesser skilled players. They had more efficient and effective search strategies that were dependent on the specific and distinctive constraints imposed by the game setting (e.g., ball distance relative to the player). Results provide a more complete representation of the processes mediating superior anticipation and decision making expertise during dynamic and temporal-constrained open-play situations involving 11 versus 11 players as opposed to more microstates and closed situations of the game presented in previous studies (e.g., McMorris & Colenso, 1996; Savelsbergh, Onrust, Rouwenhorst, & van der Kamp, 2006; Vaeyens et al., 2007b). Skilled soccer players in Chapters 3 and 4 made more verbal report statements indicating greater cognitive processing which assessed the game setting and anticipated potential future events, including the planning of decisional responses to the possible outcome scenarios. Additionally, the skilled players' cognitive processing strategies evidenced differences between the two task constraints within the game. These data indicate that skilled players may possess greater and more elaborate domain- and task-specific memory representations to solve a particular problem during actual performance. These results can be interpreted as evidence supporting the long-term working memory theoretical model of expertise (LTMW; Ericsson & Kintsch, 1995). LTWM holds that experts possess and activate more superior and sophisticated domain-specific memory representations. These representations permit them to easily access and retrieve specific information of current scenarios and, therefore, facilitate better anticipation and decision making judgements compared with less expert peers.

An enhanced knowledge of how the different perceptual and cognitive processes operate across the diverse task and situations within the performance setting provides a wealth of information that may help those involved in the study and development of expert performance across a range of different domains.

The findings presented in Experiment 6 highlighted a continuous and dynamic interaction between the different perceptual-cognitive skills during performance. Moreover, their importance varied significantly as a function of the task constraint (i.e., far vs. near task). When the ball was far away from the player/participant, skilled soccer players appeared to rely more on the identification of familiarity in patterns of play. In contrast, when the ball was nearer to the player/participant, they allocated their attention to the postural orientation of opponents or teammates (with particular consideration to the player in possession), as well as to what their opponents were likely to do in advance of the actual event (i.e., situational probabilities). These data generally supported the eye-movement results from Experiment 5 and previous visual search research using soccer simulations of different situational environment constraints (Vaeyens et al., 2007a, b; Williams et al., 1994; Williams & Davids, 1998).

The findings in Chapter 4 have significant implications for the manner in which scientists and practitioners try to test and train perceptual-cognitive skills across sport domains. Most previous tests and/or training interventions have been designed to examine or improve a very specific perceptual-cognitive process or a component skill (e.g., advance cue utilisation), within a fairly narrow or restricted context (e.g., penalty-kick in soccer). In this study, evidence suggests that the different perceptual-cognitive skills interact in a highly dynamic manner during performance. Therefore, the value of using a reductionist approach to try to capture and/or train single component skills in isolation may be questioned. Designing and developing tasks where the key perceptual-cognitive skills are tested or trained simultaneously in the manner they would be used during actual performance may be the way forward.

In Chapter 5, the participation history profiles of participants who were skilled high-performing, skilled low-performing or recreational-level on the test of anticipation and decision making were recorded. The average hours accumulated per year during childhood in soccer-specific play activity was the strongest predictor of superior anticipation and decision making performance and differentiated the skill groups. Findings provided evidence to suggest that domain-specific deliberate play activity between 6 and 12 years of age may be a key element of the development of these 'game intelligence' skills in soccer (e.g., Ford et al., 2009). During this type of activity there may be significantly more opportunities for players to improvise, adapt/learn and, engage in a variety of situations that re-create those conditions that are essential at the elite level. This increased variety and greater opportunity for continuous anticipation and creative/tactical decision making may help facilitate the acquisition of resilient and adaptive perceptual-cognitive skills. Moreover, early involvement in this type of unstructured, discovery-based environment practice is thought to have a positive effect on an individual's general motivation and willingness to engage in further structured, coach-lead practice activities as well as preventing burnout and/or dropout from the sport (Côté, Baker, & Abernethy, 2007).

Soccer-specific practice activity during adolescence was also a contributing factor to the variance in anticipation and decision making scores across participants, albeit to a lesser extent. Additionally, no differences were reported for number of other sports engaged in during development across groups. Data lead to the suggestion that the skilled high-performing group were following the 'early engagement' hypothesis proposed by Ford and colleagues (2009), rather than the 'early diversification' pathway (Côté, 1999). According to this hypothesis or pathway, athletes participate mainly in deliberate play in the primary sport during childhood, engaging in minimal sporting diversity in other sports, participating in some deliberate practice in the main sport during childhood, and late or delayed (i.e., 13 to 15 years of age) engagement in large amounts of deliberate practice in the primary domain. It may be that the early engagement development pathway is a prerequisite if athletes are to accrue the amount of practice time required to be competitive in that sport domain, particularly in countries where certain sports dominate the culture (e.g., soccer in Europe and South America). Thus, findings highlight the need to build a proper and correctly balanced pathway between domain-specific deliberate practice (e.g., team practice) and deliberate play activities (e.g., street soccer) in the development and attainment of the highest levels of expert perceptual, cognitive and, motor performance in the sport of soccer.

Overall, the findings from this thesis extend the research on perceptual-cognitive expertise and its acquisition providing an important contribution to the development of more refined theories of expertise and a principled basis for those involved in talent identification and development to design the most appropriate learning, training, and practice environments for performers.

Limitations and Directions for Future Research

The issue of how best to capture skilled perceptual-cognitive performance in the laboratory or field settings, using a representative task(s) within a particular domain, remains an important topic (e.g., Williams & Ericsson, 2005). Although in Chapter 2 an attempt was made to develop a dynamic, 11 versus 11 soccer representative video simulation task using one of the most realistic replication of that environment that is currently feasible under controlled conditions in the laboratory, some functional limitations on performance may still persist. A particular concern is that video simulation tasks may, in some cases, fail to represent the selection of stimuli available for perception and action in a performer's natural environment (see Brunswik, 1956; Dhami et al., 2004; Gibson, 1979). Yet, video simulations can provide a significant advantage, particularly in sporting tasks where sequences of events are rarely (if ever) repeated (e.g., as the one applied in this thesis), enabling sequences of action to be reproduced in a consistent manner from trial to trial and across participants. In future, researchers should invest greater effort in attempting to enhance and refine experimental designs by ensuring that experimental task constraints represent the specificity of the relations between the participant and the performance environment (e.g., see Dicks et al., 2010a).

In Chapters 3 and 4, holistic and global analyses of perceptual-cognitive expertise across dynamic and externally paced situations in soccer were attempted. Yet, there is still a lack of extensive literature attempting to employ more inclusive and multidimensional approaches to expertise in sport by combining different types of process-tracing measures and task manipulations, particularly in more complex and less explored sporting scenarios such as continuous open-play situations in team ball sports (e.g., see Ward & Williams, 2003). A more detailed description of the structure of the underlying perceptual-cognitive processes is critical to further knowledge and develop more complete conceptual models of expert performance in sport. It is possible that different process-tracing measures may identify somewhat unique strategies thereby providing support for one another, enhancing understanding of the important differences between individuals and skill levels (Williams & Ward, 2007).

Additionally, Chapter 4 showed how the different perceptual-cognitive skills interact and that their importance differs as a function of distinct situational task constraints within the game. However, a range of additional factors or constraints, beyond those examined in this thesis, may influence how important different perceptual-cognitive skills are at any given moment when making anticipatory and decision making judgments (Williams, 2009). For example, Williams and Elliot (1999) showed that emotions such as cognitive anxiety represent important constraints on visual search behaviours in dynamic sport contexts (e.g., high anxiety causes some degree of peripheral narrowing, reducing peripheral vision processing). In future, researchers should examine how these different constraints, such as transient organismic (e.g., physiological fatigue, arousal, or stress) and environmental factors (e.g., crowd noise, playing surface, or ambient temperature) may influence the importance of these perceptual and cognitive skills during performance.

Moreover, the use of the expert-novice approach in Chapters 2, 3, and 4 may lead to within-group variability of presumed skill levels and of the characteristics of skill (i.e., by forming groups of players on the basis of their team's level of competition). An alternative approach would be to use an objective within-task criterion to stratify participants into groups on the basis of their level of performance on a specific test or battery of tests (e.g., see Vaeyens et al., 2007b; Chapter 5). Another progression would be to identify a very small sample of athletes with truly exceptional levels of perceptual-cognitive skill for more detailed investigation using single case study designs. Such approach would avoid the tendency that averaging data can mask observations of functional levels of performance variability across individuals (Withagen & Chemero, 2009).

The use of retrospective recall data collection in Chapter 5 may be prone to memory inaccuracies by the participants when asked to recall activities from years ago. Steps were employed to validate the data and check for any biases, which revealed reliable and objective results that are comparable with those from other published reports (Ford & Williams, 2008; Hodges, Kerr, Starkes, Weir, & Nananidou, 2004). Moreover, this study showed the co-occurrence of superior perceptual-cognitive expertise in soccer players and their engagement in high amounts of certain soccer activities. In future, research is needed to better identify the specific types of activities that players engage in throughout their development stages which lead to adaptive changes in expertise, perhaps by conducting a more fine grained longitudinal analysis of these activities in combination with monitoring changes in different aspects of performance (e.g., anticipation and decision making) over time. In addition, future research towards detailed causal accounts of specific adaptations that occur during the development of expert performers is required (Ericsson, 2003a). Traditional learning studies (e.g., training interventions) may be applied for this purpose in an effort to explore causal links between engagement in certain types of practice activities and/or the strategies employed (e.g., instructional processes) and specific changes/adaptations in particular performance attributes such as the decision making skill. Finally, a more sophisticated micro-level analysis of these specific practice and instructional activities in 'in situ', through detailed time-use, video analysis may help provide a window into the nature of these types of activities in soccer and across other sports (e.g., see Ford et al., 2010b).

Thus, in general, several exciting opportunities and potential topics that merit additional research remains for those interested in extending current knowledge and understanding of those factors that contribute to perceptual-cognitive expertise in sport.

Concluding Remarks

In conclusion, the findings presented in this thesis have provided a holistic analysis of perceptual-cognitive expertise and its acquisition in soccer. The research has addressed a number of perceived shortcomings and fundamental problems in the sport expertise literature by employing the expert performance approach as a guiding framework. The thesis probed the nature, processes, and component skills that mediate anticipation and decision making across various dynamic and externally paced soccer situations and determined the specific type of activities that lead to the acquisition and development of the mediating mechanisms. The design of a representative soccer task simulation was used to identify skilled players more efficient and effective visual search behaviours and the cognitive thought strategies that were employed as a function of the unique situation and task constraints imposed by the game context.

Furthermore, the thesis has provided evidence for the existence of a highly dynamic and continuous interaction between the different perceptual-cognitive skills during performance, with their relative importance varying from one situation to the next to facilitate appropriate anticipation and decision making in the competitive setting. The findings suggest that several constraints influence the importance of different perceptual-cognitive skills and their mediating processes when making anticipation and decisional judgments. Findings have significant implications for the manner in which scientists and/or practitioners try to capture and enhance these component skills across (sporting) domains.

Finally, the development of perceptual-cognitive expertise in soccer players was shown to depend primarily on the prolonged adaptations to domain-specific deliberate play activities (e.g., street soccer) during childhood in conjunction with domain-specific deliberate practice later on during adolescence, albeit to a less extent. These findings highlighted the need to establish an appropriate balance between participation in soccer-specific deliberate practice and play activity(ies) during the development process, thus providing a principled basis for those involved in talent development to create the most appropriate learning and practice environments. Overall, this thesis has broadened and extended the perceptual-cognitive expertise literature, having both theoretical and practical implications, and offering some promising avenues for future research in the area.

References

Abernethy, B. (1990). Expertise, visual search, and information pick-up in squash. *Perception, 19*, 63-77.

Abernethy, B., Thomas, K. T., & Thomas, J. T. (1993). Strategies for improving understanding of motor expertise (or mistakes we have made and things we have learned!). In J. L. Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise* (pp. 317-356). Amsterdam, Netherlands: Elsevier.

Araújo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioral setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology, 19*, 69-78.

Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine (Auckland, N.Z.), 26*, 217-238.

Berry, J., Abernethy, B., & Côté, J. (2008). The contribution of structured activity and deliberate play to the development of expert perceptual and decision-making skill. *Journal of Sport & Exercise Psychology, 30*, 685-708.

Bland, J. M., & Altman, D. G. (2007). Agreement between methods of measurement with multiple observations per individual. *Journal of Biopharmaceutical Statistics, 17*, 571-582.

Brunswik, E. (1956). *Perception and the representative design of psychological experiments* (2nd ed.). Berkeley, CA: University of California Press.

Catteeuw, P., Helsen, W., Gilis, B., Van Roie, E., & Wagemans, J. (2009). Visual scan patterns and decision-making skills of expert assistant referees in offside situations. *Journal of Sport & Exercise Psychology, 31*, 786-797.

Causer, J., Holmes, P. S., Smith, N. C., & Williams, A. M. (2011). *Anxiety, movement kinematics, and visual attention in elite-level performers. Emotion, 11*, 595-602.

Chase, W., & Simon, H. A. (1973). The mind eye's in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215-281). San Diego, CA: Academic Press.

Côté, J. (1999). The influence of the family in the development of talent in sport. *The Sport Psychologist, 13*, 395-417.

Côté, J., Baker, J., & Abernethy, B. (2007). Practice and play in the development of sport expertise. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of sport psychology* (pp. 184-202). Hoboken, NJ: John Wiley & Sons.

Côté, J., Ericsson, K. A., & Law, M. P. (2005). Tracing the development of athletes using retrospective interview methods: A proposed interview and validation procedure for reported information. *Journal of Applied Sport Psychology, 17*, 1-19.

Côté, J., & Hay, J. (2002). Children's involvement in sport: A developmental perspective. In J. M. Silva & D. Stevens (Eds.), *Psychological foundations of sport* (pp. 484–502). Boston, MA: Merrill.

Davids, K. (2008). Designing representative task constraints for studying visual anticipation in fast ball sports: What we can learn from past and contemporary insights in neurobiology and psychology. *International Journal of Sport Psychology, 39*, 166-177.

de Groot, A. D. (1965). *Thought and choice in chess*. The Hague, Netherlands: Mouton.

de Oliveira, R. F., Damisch, L., Hossner, E.-J., Oudejans, R. R. D., Raab, M., Volz, K. G., & Williams, A. M. (2009). The bidirectional links between decision-making, perception and action. In M. Raab, J. G. Johnson, & H. R. Heekeren (Eds.), *Progress in brain research: Vol. 174. Mind and motion: The bidirectional link between thought and action* (pp. 85-93). Amsterdam, Netherlands: Elsevier.

Deakin, J. M., Côté, J., & Harvey, A. S. (2006). Time budgets, diaries, and analyses of concurrent practice activities. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 303-318). New York, NY: Cambridge University Press.

Dhami, M. K., Hertwig, R., & Hoffrage, U. (2004). The role of representative design in an ecological approach to cognition. *Psychological Bulletin, 130*, 959-988.

Dicks, M., Button, C., & Davids, K. (2010a). Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action. *Attention, Perception, & Psychophysics, 72*, 706-720.

Dicks, M., Davids, K., & Button, C. (2009). *Representative task designs for the study of perception and action in sport. International Journal of Sport Psychology, 40*, 506-524.

Dicks, M., Davids, K., & Button, C. (2010b). Individual differences in the visual control of intercepting a penalty kick in association football. *Human Movement Science, 29*, 401-411.

Dittrich, W. H. (1999). Seeing biological motion: Is there a role for cognitive strategies? In A. Braffort, R. Gherbi, S. Gibet, J. Richardson, & D. Teil

(Eds.), *Gesture-based communication in human-computer interaction* (pp. 3-22). Berlin, Germany: Springer.

Dittrich, W. H., & Lea, S. E. G. (1994). *Visual perception* of *intentional motion. Perception, 23*, 253-268.

Eccles, D. W. (2012). Verbal reports of cognitive processes. In G. Tenenbaum, R. C. Eklund, & A. Kamata (Eds.), *Measurement in sport and exercise psychology*. Champaign, IL: Human Kinetics.

Ericsson, K. A. (1998). The scientific study of expert levels of performance: General implications for optimal learning and creativity. *High Ability Studies, 9*, 75-100.

Ericsson, K. A. (2003a). Development of elite performance and deliberate practice. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports. Advances in research on sport expertise* (pp. 49-83). Champaign, IL: Human Kinetics.

Ericsson, K. A. (2003b). How the expert performance approach differs from traditional approaches to expertise in sport: In search of a shared theoretical framework for studying expert performance. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert performance in sports. Advances in research on sport expertise* (pp. 371-402). Champaign, IL: Human Kinetics.

Ericsson, K. A. (2004). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine, 10*, S1–S12.

Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge Handbook of*

Expertise and Expert Performance (pp. 683-702). New York, NY: Cambridge University Press.

Ericsson, K. A. (2007a). Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology, 38*, 4-43.

Ericsson, K. A. (2007b). Toward a science of expert and exceptional performance in Sport: A reply to the Commentaries. *International Journal of Sport Psychology, 38*, 109-123.

Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist, 49*, 725-747.

Ericsson, K. A., Charness, N., Feltovich, P. J., & Hoffman, R. R. (2006). *The Cambridge handbook of expertise and expert performance*. New York, NY: Cambridge University Press.

Ericsson, K. A., & Delaney, P. F. (1999). Long-term working memory as an alternative to capacity models of working memory in everyday skilled performance. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 257-297). New York: Cambridge University Press.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102*, 211-245.

Ericsson, K. A., & Kirk, E. (2001). *Instructions for giving retrospective verbal reports*. Tallahassee, FL: Florida State University.

Ericsson, K. A., Krampe, R., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: evidence on maximal adaptations on task constraints. *Annual Review of Psychology, 47*, 273-305.

Ericsson, K. A., Nandagopal, K., & Roring, R. W. (2009). Toward a science of exceptional achievement: Attaining superior performance through deliberate practice. *Annals of New York Academy of Science, 1172*, 199-217.

Ericsson, K. A., Patel, V. L., & Kintsch, W. (2000). How experts' adaptations to representative task demands account for the expertise effect in memory recall: Comment on Vicente and Wang (1998). *Psychological Review, 107*, 578-592.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (Rev. ed.). Cambridge, MA: Bradford books/MIT Press.

Ericsson, K. A., & Smith, J. (1991). Prospects and limits of the empirical study of expertise: An introduction. In K. A. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 1-38). New York, NY: Cambridge University Press.

Ericsson, K. A., & Towne, T. J. (2010). Expertise. *Wiley Interdisciplinary Reviews: Cognitive Science, 1*, 404-416.

Ericsson, K. A., & Ward, P. (2007). Capturing the naturally-occurring superior performance of experts in the laboratory: Toward a science of expert and exceptional performance. *Current Directions in Psychological Science, 16*, 346-350.

Ericsson, K. A., & Williams, A. M. (2007). Capturing naturally occurring superior performance in the laboratory: Translational research on expert performance. *Journal of Experimental Psychology: Applied, 13*, 115-123.

Ford, P. R., Hodges, N. J., & Williams, A. M. (in press). Expert sports performance and its development. In S. B. Kaufman (Ed.), *Beyond "talent or practice?": The multiple determinants of greatness*. Oxford, UK: Oxford University Press.

Ford, P. R., Low, J., McRobert, A. P., & Williams, A. M. (2010a). Developmental activities that contribute to high or low performance by elite cricket batters when recognising type of deliveries from bowlers' advanced postural cues. *Journal of Sport & Exercise Psychology, 32*, 638-654.

Ford, P. R. Ward, P., Hodges, N. J., & Williams, A. M. (2009). The role of deliberate practice and play in career progression in sport: The early engagement hypothesis. *High Ability Studies, 20*, 65-75.

Ford, P. R., & Williams, A. M. (2008). The effect of participation in Gaelic football on the development of Irish professional soccer players. *Journal of Sport & Exercise Psychology, 30*, 709-722.

Ford, P. R., Yates, I., & Williams, A. M. (2010b). An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: Exploring the link between science and application. *Journal of Sports Sciences, 28*, 483-495.

Franks, I. M., & Hanvey, T. (1997). Cues for goalkeepers: High-tech methods used to measure penalty shot response. *Soccer Journal, 42*, 30-33.

Galton, F. (1869). *Hereditary genius: An enquiry into its laws and consequences*. London, UK: MacMillan.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.

Gottsdanker, R. M., & Kent, K. (1978). Reaction time and probability on isolated trials. *Journal of Motor Behavior, 10*, 233-238.

Hays, R. T., & Singer, M. J. (1989). *Simulation fidelity in training system design: Bridging the gap between reality and training*. New York, NY: Springer.

Helsen, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology, 13*, 1-27.

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport & Exercise Psychology, 20*, 12-34.

Kelso, J. A. S. (1995). Dynamic patterns: The self-organization of brain and behavior. Cambridge, MA: MIT Press.

Hodges, N. J., Huys, R., & Starkes, J. L. (2007). Methodological review and evaluation of research in expert performance in sport. In G. Tenenbaum & R. C. Eklund (Eds.). *Handbook of sport psychology* (3rd ed.) (pp. 161–183). Hoboken, NJ: John Wiley & Sons.

Hodges, N. J., Kerr, T., Starkes, J. L., Weir, P., & Nananidou, A. (2004). Predicting performance from deliberate practice hours for triathletes and swimmers: What, when and where is practice important? *Journal of Experimental Psychology: Applied, 10*, 219-237.

Mann, D. L., Abernethy, B., & Farrow, D. (2010). Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychologica, 135*, 17-23.

Huys, R., Cañal-Bruland, R., Hagemann, N., Beek, P. J., Smeeton, N. J., & Williams, A. M. (2009). Global information pickup underpins anticipation of tennis shot direction. *Journal of Motor Behavior, 41*, 158-170.

MacMahon, C., Helsen, W. F., Starkes, J. L., & Weston, M. (2007). Decision-making skills and deliberate practice in elite association football referees. *Journal of Sports Sciences, 25*, 65-78.

Mann, D. L, Farrow, D., Shuttleworth, R., & Hopwood, M. (2009). The influence of viewing perspective on decision-making and visual search behavior in an invasive sport. *International Journal of Sport Psychology, 40*, 546-564.

Marteniuk, R. G. (1976). *Information processing in motor skills.* New York, NY: Holt, Rinehart, & Winston.

McMorris, T., & Colenso, S. (1996). Anticipation of professional soccer goalkeepers when facing right- and left-footed penalty kicks. *Perceptual and Motor Skills, 82*, 931-934.

McMorris, T., Copeman, R., Corcoran, D., Saunders, G., & Potters, S. (1993). Anticipation of soccer goalkeepers facing penalty kicks. In T. Reilly, J. Clarys, & A. Stibbe (Eds.), *Science and football II* (pp. 250-253). London, UK: E. & F. N. Spon.

McPherson, S. L. (1999). Tactical differences in problem representations and solutions in collegiate varsity and beginner female tennis players. *Research Quarterly for Exercise and Sport, 70*, 369-384.

McPherson, S. L. (2000). Expert-novice differences in planning strategies during collegiate singles tennis competition. *Journal of Sport & Exercise Psychology, 22*, 39-62.

McPherson, S. L. (2008). Tactics: Using knowledge to enhance sport performance. In D. Farrow, J. Baker, & C. MacMahon (Eds.), *Developing sport expertise: Researchers and coaches put theory into practice* (pp. 155-171). London, UK: Routledge.

McPherson, S. L., & Kernodle, M. W. (2003). Tactics, the neglected attribute of expertise: Problem representations and performance skills in tennis. In J. L.

Starkes & K. A. Ericsson (Eds.), *Expert performance in sports: Advances in research on sport expertise* (pp. 137-167). Champaign, IL: Human Kinetics.

McPherson, S. L., & Kernodle, M. W. (2007). Mapping two new points on the tennis expertise continuum: Tactical skills of adult advanced beginners and entry-level professionals during competition. *Journal of Sports Sciences, 25*, 945-959.

McRobert, A. P., Ward, P., Eccles, D. W. & Williams, A. M. (2011). The effect of manipulating context-specific information on perceptual–cognitive processes during a simulated anticipation task. *British Journal of Psychology, 102*, 519-534.

McRobert, A. P., Williams, A. M., Ward, P., & Eccles, D. W. (2009). Tracing the process of expertise in a simulated anticipation task. *Ergonomics, 52*, 474-483.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.

Newell, A., & Simon, H. A. (1972). *Human problem solving.* Englewood Cliffs, NJ: Prentice-Hall.

North, J. S., & Williams, A. M. (2008). Identifying the critical time period for information extraction when recognizing sequences of play. *Research Quarterly for Exercise and Sport, 79*, 268-273.

North, J. S., Williams, A. M., Hodges, N., Ward, P., & Ericsson, K. A. (2009). Perceiving patterns in dynamic action sequences: Investigating the processes underpinning stimulus recognition and anticipation skill. *Applied Cognitive Psychology, 23*, 878-894.

North, J. S., Ward, P., Ericsson, K. A., & Williams, A. M. (2011). Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory, 19,* 155-168.

Oudejans, R., van de Langenberg, R., & Hutter, R. (2002). Aiming at a far target under different viewing conditions: Visual control in basketball jump shooting. *Human Movement Science, 4,* 457-480.

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology, 33,* 146-155.

Radlo, S. J., Janelle, C. M., Barba, D. A., & Frehlich, S. G. (2001). Perceptual decision making for baseball pitch recognition: Using P300 latency and amplitude to index attentional processing. *Research Quarterly for Exercise and Sport, 72,* 22-31.

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences, 18,* 668-676.

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2011). Identifying the processes underpinning anticipation and decision-making in a dynamic time-constrained task. *Cognitive Processing, 12,* 301-310.

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (in press). The processes underlying 'game intelligence' skills in soccer players. In H. Nunome, B. Dawson, & B. Drust (Eds.), *Science and Football VII.*

Savelsbergh, G. J. P., Onrust, M., Rouwenhorst, A., & van der Kamp, J. (2006). Visual search and locomotion behaviour in a four-to-four football tactical position game. *International Journal of Sport Psychology, 37,* 248-265.

Savelsbergh, G .J. P., van der Kamp, J., Williams, A. M., & Ward, P. (2005). Anticipation and visual search behaviour in expert soccer goalkeepers. *Ergonomics, 48*, 1686-1697.

Savelsbergh, G. J. P., Williams, A. M., van der Kamp, J., & Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences, 20*, 279-287.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American Scientist, 61*, 394-403.

Singer, R., Cauraugh, J., Chen, D., Steinberg, G. M., & Frehlich, S. G. (1996). Visual search, anticipation, and reactive comparisons between highly-skilled and beginning tennis players. *Journal of Applied Sport Psychology, 8*, 9-26.

Soberlak, P., & Côté, J. (2003). The developmental activities of elite ice hockey players. *Journal of Applied Sport Psychology, 15*, 41-49.

Starkes, J. L. (1993). Motor experts: Opening thoughts. In J. L. Starkes & F. Allard (Eds.), *Cognitive issues in motor expertise* (pp. 3-15). Amsterdam, Netherlands: Elsevier.

Starkes, J. L., & Ericsson, K. A. (2003). *Expert performance in sports: Advances in research on sport and expertise*. Champaign: IL, Human Kinetics.

Starkes, J. L., Helsen, W. F., & Jack, R. (2001). Expert performance in sport and dance. In R. N. Singer, H. A. Hausenblas, & C. M. Janelle (Eds.), *Handbook of research in sport psychology* (pp. 174-201). New York, NY: John Wiley & Sons.

Tenenbaum, G., Levy-Kolker, N., Sade, S., Liebermann, D. G., & Lidor, R. (1996). Anticipation and confidence of decisions related to skilled performance. *International Journal of Sport Psychology, 27*, 293-307.

Thomas, J. R., Nelson, J. K., & Silverman, S. J. (2005). *Research methods in physical activity* (5th ed.). Champaign, IL: Human Kinetics.

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L., & Philippaerts, R. M. (2007a). The effects of task constraints on visual search behavior and decision-making skill in youth soccer players. *Journal of Sport & Exercise Psychology, 29,* 147-169.

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L., & Philippaerts, R. M. (2007b). Mechanisms underpinning successful decision making in skilled youth soccer players: An analysis of visual search behaviors. *Journal of Motor Behavior, 39,* 395-408.

van der Kamp, J., Rivas, F., van Doorn, H., & Savelsbergh, G. (2008). Ventral and dorsal contributions in visual anticipation in fast ball sports. *International Journal of Sport Psychology, 39,* 100-130.

Vickers, J. N. (2007). *Perception, cognition, and decision training: The quiet eye in action.* Champaign, IL: Human Kinetics.

Ward, P., Hodges, N. J., Starkes, J., & Williams, A. M. (2007). The road to excellence: deliberate practice and the development of expertise. *High Ability Studies, 18,* 119-153.

Ward, P. Suss, J., Eccles, D. W., Williams, A. M., & Harris, K. R. (2011). Skill-based differences in option generation in a complex task: A verbal protocol analysis. *Cognitive Processing, 12,* 289-300.

Ward, P., & Williams, A. M. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport & Exercise Psychology, 25,* 93-111.

Ward, P., Williams, A. M., & Bennett, S. J. (2002). Visual search and biological motion perception in tennis. *Research Quarterly for Exercise and Sport, 73*, 107-112.

Ward, P., Williams, A. M., & Ericsson, K. A. (2003). Underlying mechanisms of perceptual-cognitive expertise in soccer. *Journal of Sport & Exercise Psychology, 25*, S136.

Ward, P., Williams, A. M., & Hancock, P. A. (2006). Simulation for performance and training. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance* (pp. 243-262). New York, NY: Cambridge University Press.

Weissensteiner, J., Abernethy, B., Farrow, D., & Müller, S. (2008). The development of anticipation: A cross-sectional examination of the practice experiences contributing to expertise in cricket batting. *Journal of Sport & Exercise Psychology, 30*, 663-684.

Wickens, C. D. (1992). *Engineering psychology and human performance* (2nd ed.). New York, NY: Harper Collins.

Williams, A. M. (2009). Perceiving the intentions of others: How do skilled performers make anticipation judgments? In M. Raab, J. G. Johnson, & H. R. Heekeren (Eds.), *Progress in brain research: Vol. 174. Mind and motion: The bidirectional link between thought and action* (pp. 73-83). Amsterdam, Netherlands: Elsevier.

Williams, A. M., & Burwitz, L. (1993). Advance cue utilisation in soccer. In T. Reilly, J. Clarys, & A. Stibbe (Eds.), *Science and football II* (pp. 239-244). London, UK: E. & F. N. Spon.

Williams, A. M., & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly for Exercise and Sport, 69*, 111-128.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport, 65*, 127-135.

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sport*. London, UK: E. & F. N. Spon.

Williams, A. M., & Elliott, D. (1999). Anxiety and visual search strategy in karate. *Journal of Sport & Exercise Psychology, 21*, 362-375.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science, 24*, 283-307.

Williams, A. M., Ericsson, K. A., Ward, P., & Eccles, D. W. (2008). Research on expertise in sport: Implications for the military. *Military Psychology, 20*, S123–S145.

Williams, A. M., & Ford, P. R. (2008). Expertise and expert performance in sport. *International Review of Sport and Exercise Psychology, 1*, 4-18.

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Applied Cognitive Psychology, 25*, 432-442.

Williams, A. M., & Hodges, N. J. (2005). *Skill acquisition in sport: Research, theory and practice*. London, UK: Routledge.

Williams, A. M., Hodges, N. J., North, J., & Barton, G. (2006). Perceiving patterns of play in dynamic sport tasks: Investigating the essential information underlying skilled performance. *Perception, 35*, 317-332.

Williams, A. M., Janelle, C. J., & Davids, K. (2004). Constraints on visual behavior in sport. *International Journal of Sport and Exercise Psychology, 2*, 301-318.

Williams, A. M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Sciences, 18*, 657-667.

Williams, A. M., & Ward, P. (2007). Anticipation and decision making: Exploring new horizons. In G. Tenenbaum & R. Eklund (Eds.), *Handbook of Sport Psychology* (3rd ed.) (pp. 203-223). Hoboken, NJ: John Wiley & Sons.

Williams, A. M., Ward, P., Ward, J. D., & Smeeton, N. J. (2008). Domain specificity, task specificity, and expert performance. *Research Quarterly for Exercise and Sport, 79*, 428-433.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. (2002). Anticipation skill in a real-world task: Measurement, training, and transfer in Tennis. *Journal of Experimental Psychology: Applied, 4*, 259-270.

Withagen, R., & Chemero, A. (2009). Naturalizing perception: Developing the Gibsonian approach to perception along evolutionary lines. *Theory & Psychology, 19*, 363-389.

Yang, S. C. (2003). Reconceptualizing think-aloud methodology: Refining the encoding and categorizing techniques via contextualized perspectives. *Computers in Human Behavior, 19*, 95-115.

Zijlstra, F. R. H. (1993). *Efficiency in work behavior: A design approach for modern tools*. Delft, Netherlands: Delft University Press.

Appendix

List of Publications and Presentations

Publications

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2011). Identifying the processes underpinning anticipation and decision-making in a dynamic time-constrained task. *Cognitive Processing, 12*, 301-310.

Roca, A., Williams, A. M., & Ford, P. R. (in press). Developmental activities and the acquisition of superior anticipation and decision making in soccer players. *Journal of Sports Sciences.*

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (in press). The processes underlying 'game intelligence' skills in soccer players. In H. Nunome, B. Dawson, & B. Drust (Eds.), *Science and Football VII.*

Scientific Conference Presentations

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2011). *The processes underlying 'game intelligence' skills in soccer players*. Paper presented at the 7th World Congress on Science and Football, Nagoya, Japan. Abstract retrieved from http://www.shobix.co.jp/jssf/contents/supplement/files/P-189.pdf

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2011). Decision-making and anticipation in sport: The underlying processes of superior performance. In N. T. Cable, & K. P. George (Eds.), *Proceedings of the 16th Annual Congress of the European College of Sport Science: New horizons from a world heritage city* (p. 75). Liverpool, UK: European College of Sport Science.

Roca, A., Ford, P. R., & Williams, A. M. (2009). *Perceptual-cognitive skills and their interaction as a function of task and skill level in soccer: A preliminary analysis using verbal report protocols.* Paper presented at the 40th Annual Conference of the Canadian Society for Psychomotor Learning and Sport Psychology, Toronto, Canada. Abstract retrieved from http://www.scapps.org/conference/files/conference-program-2009.pdf

Applied Sports Presentations

Roca, A. (2011). *Cognitive expertise in young athletes.* Invited speaker: presented at the XI International Forum of Sport & V International Meeting of Football Coaches, Coimbra, Portugal.