# PATTERN RECOGNITION AND ANTICIPATION EXPERTISE IN SOCCER

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## Contents

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**Abstract**

The aim of the current programme of research was to gain a greater appreciation of the nature of information underpinning skilled pattern-recognition, and anticipation in the game of soccer. In Chapter 2, three experiments were undertaken to identify the specific information sources used to make recognition judgments when presented with displays involving interaction between numerous features. Findings indicated that skilled participants are particularly sensitive to relative motion information between key display features, notably the relationships between the central offensive players. From ascertaining the nature of information underpinning skilled recognition, Chapter 3 examined whether familiarity could still be perceived when only the minimal essential information was presented. Results demonstrated how skilled players were able to make successful recognition judgments when only the relative motions between the central offensive players, and/or player in possession of the ball were presented. Chapter 4 examined the relative importance of the different perceptual-cognitive skills to anticipation performance, as a function of the unique constraints of the task. This was achieved by altering the distance between the performer and ball, and presenting stimuli in video and point-light format. Evidence was provided to suggest skilled players rely on pattern-recognition skill when viewing the action from afar, with postural cue information increasing in importance for more localised and time-constrained situations. Finally, Chapter 5 implemented findings from the previous studies to investigate whether the ability to perceive familiarity could be improved through a perceptual training programme, and the extent to which this transferred to anticipation performance. Despite a significant improvement in recognition sensitivity from pre to post test, null effects were reported elsewhere. Possible reasons to account for these are discussed in further detail. Overall, the thesis extends the perceptual-cognitive expertise literature, offering both practical and theoretical implications, as well as avenues for future research.

# Chapter 1: A Prologue to Expertise Research

‘*Nil satis nisi optimum*’ is a Latin phrase that translates to ‘*nothing but the best is good enough*’. In every walks of life individuals strive to achieve excellence within their chosen field. As a result of its global appeal, the sporting domain in particular has received unrivalled attention from spectators and the media alike, in both their appreciation and criticism of expert performance in action. The popularity of The Olympic Games, World Cup, Super Bowl, Wimbledon, The Ashes, and Tour de France to name but a few, only serve to emphasise the appeal of skilled performers at the top of their game (Janelle & Hillman, 2003). A prevailing question remains as to how these sportsmen and women achieve such a level of performance. The quest to identify key factors underlying the acquisition of expert performance has stimulated much debate amongst the scientific community for numerous years (e.g., Howe, Davidson & Sloboda, 1998), whilst fuelling the partisan nature of millions of spectators week in, week out to their respective allegiances.

Expertise can be 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). Sport scientists have measured a number of factors that differentiate experts from novices, with expertise research multidisciplinary in nature, encompassing skill-based differences on a range of physiological, emotional (regulation/ coping; psychological), technical, and cognitive (tactical/strategic; perceptual/decision-making) measures (e.g., Williams & Franks, 1998). Although these discriminators of expertise are all imperative to successful performance, it is the latter cognitive domain that forms the crux of the present thesis. Before postulating over some of the reasons why skilled performers excel within their chosen field, a review of the literature on the theories of expertise provides an intriguing insight into how the research has evolved over the years to facilitate our understanding of expert performance to date.

Historically, theorists studying expertise have fallen into two schools of thought when attempting to explain the mechanisms behind expert performance, giving way to the 'nature versus nurture' debate (Ericsson, 1996; Ericsson & Lehmann, 1996; Howe, Davidson, & Sloboda, 1998). In concurrence with the early work of Galton (1869), exceptional performance was initially believed to be a result of an individual's intellectual aptitude and personal motivation. Thus, highly skilled individuals were genetically predetermined to be successful, inheriting an innate ability to achieve excellence within their chosen field that was immune to both training and practice. The alternative 'nuturist' viewpoint was that of extended practice, where regardless of hereditary capabilities, expertise arises from the accumulated duration of systematic training within a specific domain. According to some researchers, it can take in the region of 10, 000 hours or 10 years of 'deliberate practice' to attain expertise (e.g., Ericsson, Krampe, & Tesch-Romer, 1993). Exposure alone however, is not sufficient to merit expertise, as certain conditions must be met to satisfy the term 'deliberate practice'. Ericsson et al. (1993) defined three basic tenets. Firstly, practice is characterised by a strict regime of structured activities that are physically and mentally demanding for the performer, and not necessarily coach lead. Secondly, early investment should not reap financial rewards; tangible incentives are not the motivating factor for the individual, rather the drive to develop and improve stimulates their engaged participation. Lastly, practice is not necessarily to be enjoyed, though this latter point has since been refuted by some researchers (e.g., Hodges & Starkes, 1996). Proponents of this approach to skilled behaviour believe that expertise is achievable by virtually anyone, provided the individual partakes in a period of extended period of 'deliberate practice'. A less extreme 'nuturist' approach highlights the critical role of deliberate practice in attaining expertise, but also acknowledges that certain genetic factors such as ability and motivation may constrain the attainable level of performance. In support of this 'interactionist' perspective, Ericsson (2003) cites that with the exemption of certain hereditary limitations and individual differences, all elements of the body as well as human behaviour are susceptible to change with the demands of the environment.

### Theories of Memory Expertise

The study of expertise has its historical roots in mainstream psychology, and like the majority of theories, has been examined in many domains and with a variety of approaches (Ericsson, 1996; Starkes & Allard, 1993). Traditionally, however, the game of chess has been one of the main sources of scientific study. Seminal research in this area examined memory recall expertise, with the work of de Groot (1965) providing an intriguing insight into the cognitive mechanisms mediating expert performance. De Groot undertook a series of experiments to examine the complex thoughts and mechanisms that governed the selection of moves by world-class chess-players. Typically, players of various levels of expertise were asked to reconstruct meaningful board positions after having been exposed to them for a 2-15 second time lapse before removing them from view. Findings revealed how master and grandmaster level players performed this task with near perfect accuracy (an average of 93% pieces correct), whereas the performance of the lesser skilled players was not nearly as impressive (barely 50% correct). With the use of verbal/think-aloud protocols, De Groot (1965) subsequently attributed these findings to the experts' ability to rapidly perceive good chess moves as a consequence of their extensive knowledge of meaningful game configurations, whilst noting that memory for chess positions increased as a function of expertise.

Simon and Chase (1973) extended the work of de Groot (1965) to propose the first theory of expertise based on the framework of human information processing (Newell & Simon, 1972); the Chunking Theory. In their study, master and novice level chess players recalled both game-related and randomised configurations of chess pieces. The masters were only able to accurately recall chess pieces in the game-related condition, whereas no skill-based differences were apparent in the randomised condition. Findings were attributed to the master level player's ability to learn a large database of 'chunks' of information (i.e. board patterns), each of which represent a domain-specific pattern that is stored in the long-term memory. When presented with game-related board configurations, experts are able to swiftly recognise and encode stimuli as a sequence of chunks in the short-term memory, which in turn, correspond to the vast array of patterns or chunks stored in the long-term memory. By storing only a fixed number of chunks, the inherent limitations of the short-term memory (7 +/-2 items) are circumvented (Miller, 1956), allowing for the recall of many chess pieces, hence why masters perform remarkably well in memory tasks. Conversely, novice chess players simply do not have domain-specific patterns stored in their long-term memory, and thus rely on the encoding of solitary pieces, which explains their inferior performance on memory recall tasks. The Chunking Theory was also able to account for the decrement in memory recall for unstructured stimuli, given the lack of association between the random chunks encoded in the short-term memory and the domain-specific perceptual structures collated in the long-term memory. According to Simon and Chase (1973), the internal library of chunks develops over many years of experience, taking in the region of ten years to learn the large number of chunks (10,000 to 100,000) necessary to become an expert (see Ericsson et al., 1993).

While the Chunking Theory provides an intriguing insight into expert performance in memory recall tasks, subsequent critique has identified serious flaws in its tenets (e.g., Gobet & Simon, 1996b; Holding, 1985). Most notably, researchers have demonstrated how chess masters seem relatively insensitive to concurrent interference tasks explicitly designed to disrupt the contents of the short-term memory during recall (Charness, 1976; Frey & Adesman, 1976). Another limitation pertains to the notion that performers in the chunking account to memory recall are bound by the contextual information available, as external stimuli within the visual display can only be matched to stored chunks (Harris, Tashman, Ward, Ericsson, Eccles

& Williams, et al., 2006). Although this suffices for straightforward decisions where no response alternatives are necessary, such theories are fundamentally flawed in situations where an individual needs to evaluate future events, and consider alternative actions (Ericsson & Delaney, 1999). In everyday tasks, such constraints on memory recall would spell disaster, as the ability to plan ahead is crucial to successful performance (Harris et al., 2006).

In an attempt to describe a more accurate model of short-term memory, Baddeley and Hitch (1974) introduced a three part working memory model, which has since become one of the most prominent cognitive frameworks associated with the study of executive functions (i.e., the management of complex cognitive processes). The multicomponent model is composed of a central executive that controls and regulates two other subsystems; the phonological loop and the visuospatial sketchpad.

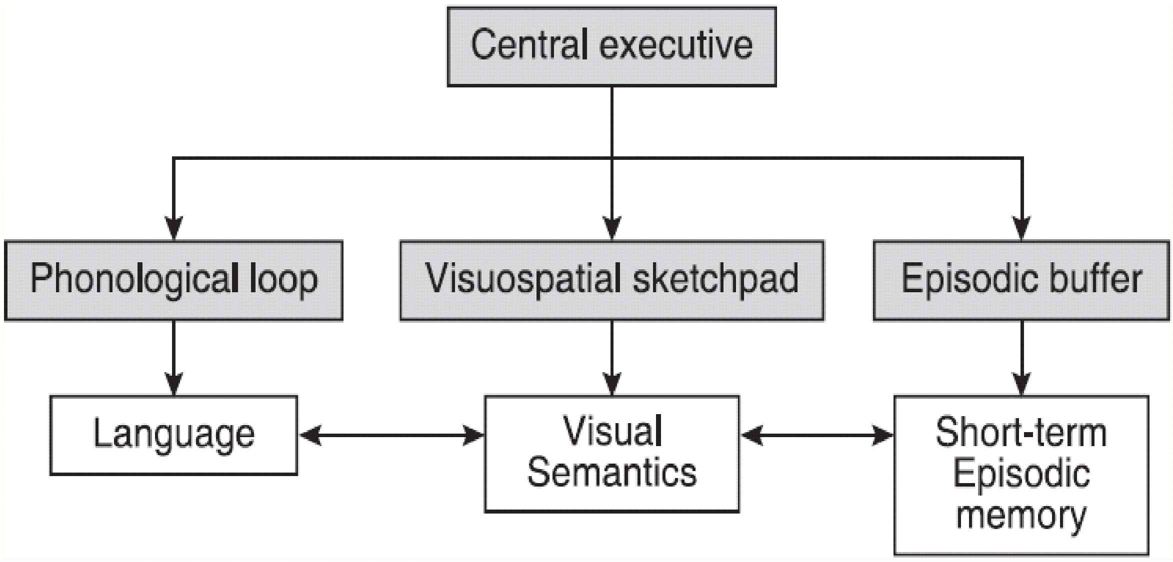


Figure 1.1: Schematic diagram of the Baddeley-Hitch (1974) working memory model.

The central executive is an essential control structure, and a significant facet in what differentiates the idea of dynamic working memory from earlier notions of short-term memory (e.g. Atkinson & Shiffrin, 1968). This supervisory system has many functions, but as a general overview it; a) regulates when information is deposited in the storage buffers; b) manages which subsystem - the phonological loop, visuospatial sketchpad, or the episodic buffer - is selected for storage; c) integrates and coordinates information between the three buffers; and d) provides a mechanism by which information held in the buffers can be inspected, transformed, and otherwise cognitively manipulated. The central executive not only determines how to expend cognitive resources, but also suppresses irrelevant information that would consume those resources (Baddeley, 1986). Evidence supporting the importance of the central executive has been attained from dual-task paradigms. Typically, performance of two simultaneous tasks requiring the use of two perceptual domains (i.e., an auditory-verbal and a visuospatial task), is nearly as efficient as performance of the tasks individually. Conversely, performance for two concurrent tasks involving the same perceptual domain, is not as efficient when compared to undertaking such tasks separately. These findings support the notion that coordination of storage demands requires the engagement of the central executive.

A plethora of research has been dedicated to the verbal working memory, known as the phonological loop, as so much everyday reasoning relies on this cognitive function. This storage buffer mainly deals with sound or phonological information, and involves two subcomponents; a *phonological store* and an *articulatory rehearsal process* (Baddeley, 1986). Auditory verbal information enters automatically into the phonological store, whereas visually presented language can be translated into a sound-based or 'auditory-phonological' code by silent articulation and subsequently be encoded into the phonological store. The phonological store acts as an 'inner ear', remembering sounds in their temporal order, and has frequently been described as an internal echo-box, a repository for sounds that reverberate momentarily before dissipating. The primary function of the articulatory process is to actively refresh such information. Acting as an 'inner voice', series of words (or speech elements) are repeated internally on a loop to prevent complete decay. Articulatory rehearsal enables verbal information in the mind's voice, to be heard again in the mind's ear and maintained in the phonological store. As a result, a continuous loop is upheld for as long as the verbal stimuli needs to be maintained in working memory. The phonological loop is presumed to be play a key role in the acquisition of vocabulary, especially in the early childhood years (e.g., Alt, 2011), as well as being vital for the learning of a second language (e.g., Masoura & Gathercole, 1999).

The visuospatial sketchpad is the second slave system in the Baddeley-Hitch (1974) model of working memory, and is assumed to hold information about what we see. As the name implies, it is used in the temporary storage and manipulation of visual (e.g. face of a friend) and spatial (e.g. arrangement of a room) information. It is thought that the visuospatial sketchpad plays an integral role in tracking where one is in relation to other objects as we move through our environment (Baddeley, 1997). The sketchpad also allows an individual to temporarily recall visual and spatial information held in the long-term memory, such as giving directions to a friend to help them navigate through a city you know well.

In 2000, Baddeley added a fourth component to the model; the episodic buffer, in order to account for some limitations associated with the original Baddeley-Hitch model (1974). The primary motivation for the introduction of a third slave system was the observation that some amnesia patients (especially highly intelligent), with seemingly no ability to encode new information in the long-term memory, had good short-term recollection of stories, eliciting considerably more information than could feasibly be held in the phonological loop (Baddeley & Wilson, 2002). The episodic buffer therefore acts as a complementary store when the other systems are overloaded or disrupted, while enabling information across domains to be integrated into time-sequenced units of visual, spatial and verbal information. Another key function is to facilitate short-term memories of complex information (i.e., episodes) to be stored. It is also assumed to have links to long-term memory and semantic meaning (Baddeley, 2000). Although still a relatively new concept, the inclusion of the episodic buffer into the working memory model appears to offer a credible solution to some abnormal findings in the literature that could not feasibly be explained by the original model.

As a result of its ability to integrate a large number of findings from work on short-term and working memory, the Baddeley-Hitch model (1974) has become the dominant view in the field of expertise. Alternative theories are however being developed to further our appreciation of the nature of the working memory system, which could potentially have significant implications for understanding why individuals differ in cognitive skills and abilities, as well as various degrees of success in their efforts to accomplish real-world goals. For example, Miyake and colleagues (2000), provide a different perspective of working memory, proposing three distinct facets of executive functions; updating, inhibition, and shifting. Firstly, updating requires the continuous monitoring and coding of incoming information for relevance to the task at hand, with ensuing revision of items held in working memory by substituting old, and no longer pertinent information, with newer more relevant information (Morris & Jones, 1990). Secondly, inhibition refers to one's ability to deliberately inhibit responses that are pre-potent in a given situation. Lastly, shifting denotes an individual's cognitive flexibility to switch between multiple tasks, operations, or mental sets (Monsell, 1996).

The Baddeley-Hitch (1974) model and the three facets of executive functions proposed by Miyake and colleagues (2000) have focussed almost exclusively on the working memory. In contrast, Simon and Chase's Chunking Theory (1973) has been criticised for its over-reliance on the short-term memory (Charness, 1976). In response, Ericsson and Kintsch (1995) developed the Long-Term Working Memory Theory (LTWM) to account for the ease with which individuals deal with complex task activities in everyday life, despite the inherent limitations of the short-term memory. According to the model, experts acquire sophisticated skills that enable them to either avoid or simply change the limits on working memory. These skills promote rapid encoding of information in long-term memory and enable selective access to this information when required, expanding the available capacity in short-term memory (Ericsson & Lehmann, 1996). Retrieval cues kept in short-term working memory facilitate immediate and efficient access to information stored in long-term memory. With extensive practice, experts index information in such a way that they can successfully anticipate future retrieval demands. This expansion of working memory provides the expert performer with greater capacity to engage in planning, reasoning, evaluation, and other key activities needed for elite performance (Ericsson & Delaney, 1999).

Although the LTWM Theory provides a sound theoretical framework for the nature of knowledge structures guiding skilled performance, its tenets have still been subjected to criticism (e.g., Gobet, 1997, 1998, 2000; Vicente & Wang, 1998). For example, Gobet (1997) describes the theory as vague and underspecified, specifically questioning the exact nature of the retrieval structures and the lack of specified time parameters for encoding information into these, as well as elaborating long-term memory schemas. Vicente and Wang (1998) also argue that the theory has not been developed sufficiently enough to account for skilled performance in a sporting context, with the majority of expertise effects documented in domains where memory recall is a contrived task, and not essential to sport (e.g., chess). They therefore developed their own cohesive theory of expertise that took into account environmental constraints; the Constraint Attunement Hypothesis (CAH). This ecological theory focuses more on the understanding of goal-relevant constraints in a domain, with exponents advocating a careful study of environmental properties before any attempt to theorise over cognitive processes (Anderson, 1990; Gibson, 1966; Vicente and Wang, 1998). The CAH is therefore a product theory of expert memory, in that the functional relation between input and output is described, yet the underlying psychological mechanisms are circumvented.

The CAH was derived from E. J. fif's (1969) theory of specificity and Rasmussen's (1985) notion of abstraction hierarchy. The theory itself predicts an expertise effect when there are goal-relevant constraints (relationships pertinent to the domain) that skilled performers can exploit to structure stimuli. According to Vicente and Wang (1998); "the more constraint available in their domain of expertise, the greater the expertise advantage can be, providing they are attuned to the goal-relevant constraints in question" (p. 36). Conversely, if one fails to attune to this information then no expertise advantage will be observed. In situations with fully random stimuli, there is no domain relevant structure/constraint evident, and thus no expertise advantage would be expected. In order to identify goal-relevant constraints, Vicente and Wang (1998) propose that individuals conduct an abstraction hierarchy; "a framework for developing a hierarchical description of the goal relevant constraints for a problem domain" (p.36). Within this, there are constraints on relationships both within and between levels of the hierarchy, which are connected by a means-end relationship (for a detailed review see; Vicente and Wang, 1998). According to Vicente and Wang (1998), the CAH can be used to explain a number of diverse empirical findings in the literature, which were not predicted by the researchers that conducted said experiments, and couldn't be explained by existing theories of memory recall (e.g., Weber & Brewer, 2003). To this end, and while a number of criticisms have been levied against the theory (e.g., Ericsson, Patel, & Kintsch, 2000; Gobet & Simon, 2000), CAH makes a novel contribution to skill acquisition and expertise effects in memory recall.

From reviewing the various accounts of expertise, it would appear that an abundance of evidence exists regarding the applicability of each theory in a variety of domains. Such an array of hypotheses has afforded researchers with a wealth of information to help facilitate and broaden our understanding of the underlying mechanisms of skilled performance, whilst inevitably provoking conflict within the literature. Although one cannot underestimate the contribution of each theory to expertise research, as a collective, they were developed as a general synopsis or overview of exceptional performance, irrespective of domain. Thus, the pertinence of each theory to a ‘specific’ practice/field proves somewhat difficult, particularly from a sporting viewpoint (e.g., Vicente & Wang, 1998). In this regard, none of theories were able to inform sport scientists and practitioners as to the specific display features expert performers perceive and encode in order to govern skilled behaviour. More specifically, an appreciation of the essential attributes that distinguish experts from novices is essential to determine which types of practice are most likely to enhance the development of expertise.

In order to better identify the exact mechanisms underpinning skilled sports performance, Ericsson and Smith (1991) proposed the ‘Expert Performance Approach’ as a new guiding framework for the study of expertise. They argue that the scientific identification of expert characteristics could be accomplished in a three 3-stage process, the first of which necessitates that performance be observed in *situ* to capture the essence of expertise in the domain of interest. This information can then be used to develop a representative task(s) that allows component skills to be accurately reproduced and simulated under controlled laboratory conditions in a holistic and reliable manner. The second stage aims to identify the underlying mechanisms that account for superior performance, by employing process-tracing measures such as verbal protocol analysis, eye-movement recordings, and/or representative task manipulations. The final stage involves efforts to provide explanations to account for how the mechanisms identified in stage two were acquired during skill development (i.e. the adaptive learning and acquisition processes), so that implications for practice and instruction can be ascertained. The growing number of practice histories profiles are typical of this stage of the expert performance approach (e.g., Hodges & Starkes, 1996; Helsen, Starkes, & Hodges, 1998; Roca, Ford, McRobert, & Williams, 2013), and include the specific type of activities that when deliberately practiced, result in associated improvements in performance (Ericsson et al., 1993).

### *Learning Theory and Instructional Design*

Although there is no one definition of learning that is universally accepted by theorists, researchers, and practitioners (Shuell, 1986), its commonly surmised as an enduring change in behaviour that results from practice or other forms of experience. Instructional design refers to the process of creating instructional experiences to make the acquisition of knowledge and skill more efficient, effective, and appealing. A brief summary of the three most commonly discussed learning theories in terms of their historic and current importance to the field of instructional design, is provided below.

Behaviourism concentrates on the study of overt actions that can be observed and measured (Good & Brophy, 1990). It views the mind as a 'black-box' in that a response to a stimulus can be viewed quantitatively, while it is not possible to accurately measure cognitive processes. The learner is essentially passive, responding to environmental stimuli. Learning is therefore defined as nothing more than the acquisition of a new behavioural pattern being repeated, until it becomes autonomous. Experiments by behaviourists identify conditioning as a universal learning process, of which there are two types, each yielding a different behavioural pattern. Classic conditioning occurs when a natural reflex responds to a stimulus. The seminal research by Pavlov (1897/1902) and his observation that dogs salivate when they eat or even see food is a classic example illustrating how a certain stimulus will produce a specific response (i.e., it is hard-wired and requires no learning). The second behavioural pattern is operant conditioning, which occurs when a response to a stimulus is reinforced. In his influential study of rats and pigeons, Skinner (1938) demonstrated how behaviour is shaped through positive or negative reinforcement which increases the probability that the antecedent behaviour will happen again. In contrast, punishment (both positive and negative) decreases the likelihood of said behaviour from reoccurring. With regards to instructional design, instructors in the behavioural account to learning, typically create measurable and observable learning outcomes among students. The use of tangible rewards and informative feedback is an important construct in order to promote reinforcement, and guide individuals in mastering a set of predictable skills or behaviours.

It has been argued that not all learning occurs through shaping and changing of behaviours, leading early educational psychologists to develop a more cognitively driven approach to learning (e.g., Piaget, 1985; Vygotsky, 1978). The cognitivism revolution subsequently replaced behaviourism in the 1960s as the dominant learning paradigm, specifically concerned with the study of the mind and how it obtains, processes, and stores information. The metaphor of the computer has commonly been used to define the theory and the accumulation of knowledge. Specifically, relevant incoming information is processed in the short-term memory before being stored away in the long-term memory as internal knowledge structures, known as schemas. Learning is therefore defined as a change in an individual's schemata.

Constructivism is another paradigm that has gained increased significance given its emphasis in the instructional design literature (e.g., Bednar, Cunningham, Duffy, & Perry, 1991; Duffy & Jonassen, 1991). Akin to cognitivism, the theory describes learning as an active, contextualised process, with individuals constructing their own understanding and knowledge of the world, based on personal experiences and hypotheses of the environment. From his work in children's education, Paiget (1985) advocates cognitive constructivism, where knowledge is actively constructed by learners based on their existing cognitive structures. This is achieved through either assimilation or accommodation. Assimilation describes how we perceive and adapt to new experiences. It is the process of reinterpreting unfamiliar information to assimilate into pre-existing cognitive schemas, where previously learned information is used to make sense of it. In contrast, accommodation occurs when incoming information does not match pre-existing schema, meaning the schema must be changed in order to accommodate this conflict and deal with the new object or situation (Stavredes, 2011). With knowledge actively constructed as oppose to passively absorbed, learning is presented as a process of active discovery. In terms of instructional design, the role of the instructor is to provide the necessary resources to encourage learners to discover principles by themselves, while affording them the opportunity to formulate their own hypotheses of the environment.

Although Vygotsky (1978) was a cognitivist, he rejected the assumption made by Piaget (1985) that it was possible to separate learning from its social context. As a result, he introduced social constructivism, describing how interaction with others facilitates cognitive development enabling the learner to attribute meaning to new information, as oppose to assimilation and accommodation. Closely allied to Bandura's social learning theory (1977), social constructivism has often been cited as a bridge between behaviourist and cognitive learning paradigms given it encompasses attention, memory, and motivation.  An essential facet in Vygotsky's theory is the 'zone of proximal development' (1978), where individuals are able to attain greater cognitive development under the guidance of teachers (or in collaboration with peers) in comparison to learning on their own. With regards to instructional design, and in direct contrast to the aforementioned cognitive constructivist approach, the teacher will offer guidance to the learner and actively encourages group work/discussion when a problem is encountered, in order to facilitate cognitive growth and learning.

### *Perceptual Learning Literature*

With the current programme of work centred on perceptual-cognitive expertise in soccer, another point of interest pertains to perceptual learning. Perception can be defined as the recognition and interpretation of sensory information, which occurs continuously in everyday life, from simple discriminations (e.g., distinguishing hot from cold), to complex classifications of spatial and temporal patterns relevant to real-world expertise (e.g., air traffic controllers). Perceptual learning is therefore a process by which the ability of the sensory systems to respond to environmental stimuli is improved through repeated experiences. There are three common theoretical approaches to perceptual learning, a brief summary of each is provided below.

The transactionalist theory advocated by Gregory (1970) argues that perception is a constructive process reliant on top-down processing. Essentially, a cognitive process that initiates with our thoughts before flowing down to lower-level functions such as the senses. Top-down processing makes use of contextual information within the environment to inform pattern-recognition judgments that are matched against prior knowledge to facilitate effective perception. For example, it is easier to comprehend difficult handwriting when reading complete sentences, rather than single or isolated words, as the surrounding words provide a context to facilitate understanding. According to Gregory (1970), a magnitude of information reaches the eye, yet by the time it gets to the brain, around 90% is lost. As a result, we make a perceptual hypothesis about what we see derived from past experiences, effectively constructing our perception of reality, with this information then stored as schemas in the long-term memory. Sensory receptors are constantly active in order extrapolate environmental information, which is then combined with previously constructed knowledge, in order to make sense of what we see.

Although the constructive view of perceptual learning has received support in the literature (e.g., Bruner, 1960), it is not without its critics. A major limitation pertains to the perceptual processes of the neonate, if indeed individuals perceive the world based on hypothesis testing and past experiences (i.e., they have yet to develop long-term memory schemas). To this end, proponents of the nativist approach to perceptual learning have provided evidence to show how new-born infants demonstrate shape constancy (Slater & Morison, 1985) and favour their mother’s voice over others (De Casper & Fifer, 1980). Another critique concerns the purported underestimation of the richness of the sensory information available in the real-world when compared to laboratory settings in which a lot of the constructivism evidence for perceptual learning has been obtained (e.g., Gibson, 1950, 1966, 1979).

The abundance of environmental information available in the real-world forms the crux of the second approach to perceptual learning. Gibson's (1950, 1966, 1979) direct theory of perception is an ecological paradigm based on the interactive relationship between the observer and their environment. An essential tenet of the theory is the notion that individuals directly pick-up environmental information via an active perceptual system, rather than passively through their senses and subsequent perceptual hypotheses (e.g., Gregory, 1970). Challenging traditional views of psychology, Gibson argued that perception is a bottom-up process, discerning from the stimulus itself. Processing of sensory information is one-directional; from the retina to the visual cortex, with each successive stage in the visual pathway carrying out ever more complex analysis of the input. Much of Gibson's earlier work centred on aviation training in World War II and improving depth perception in pilots. From his research, Gibson strongly advocated that pilots navigate themselves by means of visual observation of ground surface characteristics, as oppose to data from their vestibular of kinaesthetic senses. According to Gibson (1950, 1966, 1979), surfaces contain features sufficient to distinguish different objects from each other. These invariants in the physical world are directly accessible to the perceptual systems of humans and animals, which are attuned to pick up this information through direct perception, allowing recognition of the properties of surfaces, objects, and so forth.

Another facet of Gibson's ecological approach (1979), is that perception involves identifying the function of environmental invariants, a process he termed *affordance*: "affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (p. 127). For example, a chair allows one to sit on it, while a moving ball allows a person to catch it. According to Gibson (1979): "Different layouts afford different behaviours for different animals, and different mechanical encounters" (p. 128). To this end, different objects afford different action possibilities for different species, such that a surface may offer support for an ant, but not a hippopotamus. In order to ascertain the affordances available to a species, it is important to quantify environmental properties relative to the ability of said specie. According to Gibson, cognitive processes merely facilitate the coupling between perception and action, with observers directly perceiving the meaning and value of environmental objects. In general terms, skilful perception of the visual environment would depend on the observer's interaction with the relevant affordances and result from a tighter coupling between perception and action.

In contrast to Gibson's direct perception viewpoint (1950, 1966, 1979), Goldstone (1998) postulates a more cognitively driven approach to perceptual learning, primarily concerned with the internal mechanisms that govern the process, and mediate between the external world and cognition. According to Goldstone (1998): "perceptual learning involves relatively long-lasting changes to an organism's perceptual system that improve its ability to respond to its environment" (p.586). The mechanisms of perceptual learning include attention weighting, imprinting, differentiation, and unitisation. As a brief overview, attention weighting involves making a distinction between relevant and irrelevant stimuli. Over time, perception becomes adapted to tasks by increasing the attention paid to key dimensions and features, and disregarding those less important. Imprinting is the process of developing specialised receptors for specific stimuli. With continued exposure, detectors are further refined and strengthened such that the speed, accuracy and general fluency in which perceptual stimuli are processed is increased considerably. Topological imprinting also occurs, where the space and positions of patterns within a specific area are learned. Rather than developing independent receptors, topological imprinting ensures that a spatially organised network of receptors is created. The third process in Goldstone's cognitive approach to perceptual learning is differentiation, which occurs when stimuli that were once indistinguishable become psychologically separated, enabling more accurate distinction between the component parts. This occurs at the levels of whole stimuli and features within stimuli. The last process is unitisation which occurs when tasks that may have previously required detection of several component parts are now accomplished by detecting a single construct. For example, words and sentences may be learned individually as part of a larger set of information. When the information needs to be recalled, unitisation ensures it is recalled as a whole set of data and not a medley of disparate words and sentences.

## Identifying the Perceptual-Cognitive Discriminators of Sporting Expertise

According to the processes outlined above, performers can learn to control attention to, and process, domain-relevant environmental stimuli by grouping together pieces of information that were previously perceived as being distinct (Goldstone, 1998). The implication of such learning is that individuals can be trained to reduce perceptual uncertainty, which in turn, facilitates anticipation of future events. While anticipation is important in all walks of life, the temporally constraining nature of sport posits that the ability to predict the intentions of an opponent is essential to expert performance (Abernethy, 1987).  The return of serve in tennis, the batsman facing a fast bowler in cricket, and the goalkeeper attempting to save a penalty in soccer, are all classis examples where the speed of play highlights the need to be proactive rather than reactive when deciding upon an appropriate course of action. Numerous studies exist reporting how skilled performers demonstrate superior anticipation over their less skilled counterparts in these sports (e.g., Jones & Miles, 1978; Abernethy & Russell, 1984; Williams & Burwitz, 1993).

Despite the abundance of literature documenting skill-based differences for anticipation, there remains considerable debate as to the exact mechanisms underpinning effective performance (Williams & Ericsson, 2005; Williams & Ward, 2007). As a result of extended engagement within a particular domain, it is proposed that experts develop a range of perceptual-cognitive skills that facilitate anticipation judgments (e.g., Ward, Hodges, Starkes, & Williams, 2007). Perceptual-cognitive skill can be described as the ability to identify and acquire environmental information for integration with existing knowledge such that appropriate responses can be selected and executed (Marteniuk, 1976). 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), from military (Endsley & Smith, 1996; Russo, Kendall, Johnson, Sing, Thorne, Escolas, et al., 2005), and medical scenarios (Sowden, Davies, & Roling, 2000; Abernethy, Poolton, Masters, & Patil, 2008), to sporting contexts (cf., Williams, 2009). With regards to the latter environment, there is a growing body of literature to suggest that these skills account for a significant proportion of variance in performance between elite and sub-elite athletes (e.g., see Reilly, Williams, Nevill, & Franks, 2000; Williams, Davids, Burwitz & Williams, 1992). As performers progress through the ranks, these perceptual-cognitive, as well as technical skills are more likely to discriminate performers than anthropometric and physiological profiles (Williams & Reilly, 2000). To this end, researchers have sought to better understand the underlying psychological mechanisms that discriminate exceptional from less exceptional individuals in sport (Starkes & Ericsson, 2003). The following section provides an overview of some of the key perceptual-cognitive differences to highlight the importance of these components to superior anticipation in sport.

Early research on perceptual-cognitive expertise attempted to examine whether skilled and less skilled performers could be differentiated on their visual abilities, with optometrists and vision scientists strongly advocating such a visual hardware account of expert performance. According to Gardner and Sherman (1995) athletes need above-average levels of visual function in order to meet the demands of their sport and fulfil their role efficiently. Although intuitively appealing, empirical evidence supporting such a claim is equivocal at best (Williams, Davids, & Williams, 1999). Numerous researchers have provided evidence to suggest that skill-based differences do not emerge on more general measures of visual function, such as visual acuity and depth perception. For example, Ward, Williams, and Loran (2000) showed that elite and sub-elite soccer players between the ages of 8 and 18 years possess similar levels of visual function (as determined by standard measures of static and dynamic visual acuity, depth perception, and peripheral awareness). Helsen and Starkes (1999) provided further evidence to suggest that although the visual system may set limits to performance, these are not a prerequisite for expert performance in soccer. The lack of skill-based differences for visual information processing abilities encouraged researchers to examine the importance of other perceptual-cognitive skills assumed critical to successful anticipation and decision-making skill in sport. A brief overview of some of the major findings in this area is provided below.

### Advance Cue Utilisation

Advance cue utilisation refers to a performer's ability to make accurate predictions based on the information arising from an opponent or teammate's posture and bodily orientation, in the moments leading up to a key event, such as foot-ball contact (Williams & Burwitz, 1993; Franks & Hanvey, 1997; Savelsbergh, Williams, van der Kamp, & Ward, 2002). The ability to anticipate an opponent's actions based on partial or advance sources of information is essential because of the time constraints placed on the performer, particularly in fast ball sports (Abernethy, 1987). Typically, the film-based temporal occlusion technique has been used to elicit skill-based differences (e.g., Jones & Miles, 1978, Starkes, 1987, Abernethy, 1990). Using this approach, the action is filmed from the customary viewing perspective; the film is then selectively edited to provide the participant with varying amounts of advance and ball flight information. The participant's task is to determine what happened next and respond accordingly. Skill-based differences are most apparent at the earliest pre-contact occlusion conditions, implying that the ability to anticipate future events based on advance information is crucial to high-level performance. These findings have been demonstrated across a wide range of sports, including tennis (Jones & Miles, 1978), badminton (Abernethy & Russell, 1987), soccer (Williams & Burwitz, 1993) and field hockey (Salmela & Fiorito, 1979).

**Pattern-Recognition**

The ability of experts to 'read' patterns from within their domain of expertise in a superior manner to individuals of lesser skill appears to be as strong a defining attribute of expertise in the sports environment as it is other performance domains such as chess (e.g., Simon & Chase, 1973), bridge playing (e.g., Charness, 1979) and map reading (e.g., Howard & Kerst, 1981). The pioneering work of Allard, Graham, and Paarsalu (1980) were the first to introduce the recognition paradigm to a sporting context, effectively differentiating between expert and novice basketball players. Using this approach, players were initially presented with a viewing phase and a series of slides containing both structured (i.e., attacking patterns of play) and unstructured (e.g., time-outs or turnover situations) game conditions. In a subsequent recognition phase, half of the trials previously viewed were interspersed with novel trials, with players then required to make a familiarity judgment as to whether the trial was shown earlier in the viewing phase or not. Recognition accuracy for new and previously viewed stimuli was then taken as a dependent measure of performance. Consistent with the findings from the earlier research on chess (e.g., Simon & Chase, 1973; Charness, 1976), skilled players were significantly more accurate than less skilled players at recognising structured trials only, whereas no skill-based effects were reported for the unstructured trials. According to Allard et al. (1980), skilled basketball players are able to encode task-specific information to a deeper and more meaningful level, thus facilitating the recognition of patterns of play from their field of expertise. These findings have since been extended to various other sporting domains and regardless of whether the mode of presentation is visual (e.g., Starkes, 1987) or auditory (e.g., Weber & Brewer, 2003), and whether the elements to be recalled are opposing player positions in a team sport such as American football (e.g., Garland & Barry, 1991) and soccer (e.g., Williams, Davids, Burwitz, & Williams, 1993), or self-positions in a performance routine such as gymnastics (e.g., Imwold & Hoffman, 1983) and figure skating (e.g., Deakin & Allard, 1991), or external layouts such as the configuration of balls on the table in snooker (Abernethy, Neal, & Koning, 1994). Findings from these studies were attributed to the skilled performer's ability to successfully identify task specific structures or patterns across display features, hence why skill-based differences in recognition performance are observed for situations containing domain-specific structure, but such effects are either diminished or completely lost in situations where the usual domain-specificity is disrupted (i.e. random stimuli).

### Visual Search Behaviours

The ability of performers to pick up advance visual cues and recognise patterns/structure within stimuli, is partly determined by the manner in which why move their eyes around the display in an attempt to extract the most pertinent information. Sophisticated eye-movement registration techniques have been employed in dynamic sport settings to examine skill-based differences in visual search behaviour (for a review see Williams, 2002). Empirical evidence from a variety of domains demonstrate how experts show more pertinent search strategies, fixating on more informative areas of the display, when compared to their less skilled counterparts (e.g., Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007a,b; Williams & Davids, 1998). These differences between skill groups are assumed to be indicative of more refined selective attention processes and enhanced task-specific knowledge structures (Henderson, 2003).

Early research in this area relied on laboratory-based techniques involving static slide presentations and predominantly focussed on relatively closed skill situations, such as the penalty kick in soccer (Tyldesley, Bootsma, & Bomhoff, 1982). With significant technological advancements such as integrated head-and-eye tracking systems, there has been a progressive shift towards the analysis of gaze behaviours using dynamic film simulations (e.g., Helsen & Starkes, 1999; Vaeyens et al., 2007a, b; North, Williams, Hodges, Ward, & Ericsson, 2009), as well as field-based protocols (e.g., Martell & Vickers, 2004; Vickers & Williams, 2007). For example, Williams, Davids, Burwitz, and Williams (1994) examined the visual search strategy of experienced and inexperienced soccer defenders while attempting to anticipate final pass destination of action sequences presented from an 11vs.11 perspective on a large screen. In addition to skill-based differences relating to anticipation accuracy and response speed, eye-movement data showed how inexperienced players tended to 'ball watch', fixating more frequently on the ball and player passing the ball. In contrast, the experienced players employed a more extensive search strategy, as evidenced by more fixation locations of shorter duration on the position and movement of opponent players 'off the ball'. In a meta-analysis of three decades of empirical work in this area, Mann, Williams, Ward, and Janelle (2007) reported that the majority of studies have demonstrated how experts consistently exhibit fewer fixations of longer duration when compared to non-expert groups. Given the typically dynamic nature of sport, researchers have interpreted such visual search strategies to be more efficient, affording more time for detailed information extraction from only the most relevant environmental cues (Williams, Davids, & Williams, 1999).

Researchers have also demonstrated how the visual search strategy of an individual is not solely dependent on experience or skill level, as the unique constraints of the task will also guide search behaviour, such as the number of players involved in the action sequence (e.g., 11vs.11, 3vs.3, 1vs.1) and the player's specific functional/positional role within the team (defender vs. attacker) (see Williams & Davids, 1998; Vaeyens et al., 2007a, b). In addition, eye-movement data has shown search behaviour to deviate under conditions of excessive physiological fatigue and emotional stress, as a consequence of peripheral narrowing or hypervigilance (e.g., Janelle, Singer, & Williams, 1999; Williams & Elliott, 1999; Vickers & Williams, 2007).

**Situational Probabilities**

Skilled performers are not only more efficient at processing and extracting contextual information from the visual display, but they also make use of situational probabilities to predict future response requirements. In view of the previously discussed LTWM Theory (Ericsson & Kintsch, 1995), experts possess an array of domain-specific knowledge structures in their long-term memory, which allow them to formulate accurate a priori expectations as to what an opponent is likely to do in any given situation. During the anticipation process, experts assign many events as being highly improbable that leads to a hierarchy of probabilities being attached to the remaining events, which are then confirmed or revised on the basis of contextual information materialising from the display. Situational probability skill can be generic to a range of opponents or specific to a particular opponent, and allows performers to formulate appropriate responses based on strategic, tactical and technical considerations (Abernethy 1993; Beek, Jacobs, Daffertshofer, & Huys, 2003). Alain and colleagues (e.g., Alain & Proteau, 1980; Alain, Sarrazin, & Lacombe,1986; Alain & Sarrazin, 1990) conducted the seminal work within this area, examining how players in various racquet sports made use of situational probabilities to anticipate shot selection of their opponents. Subsequent methodological improvements through the use of more representative paradigms have enabled researchers to observe the use of situational probabilities in more open, team-ball sports. For example, Ward and Williams (2003) asked both elite and sub-elite soccer players to assign probability values to the ‘best passing’ options available to the player in possession of the ball. Film sequences of match-play situations were paused at key moments, with participants then ranking in order of likelihood the key player(s) most likely to receive the ball. Findings revealed how elite players were more adept at assigning a hierarchy of probabilities to likely events as they highlighted players who were in the best/most threatening positions to receive the ball, as determined by a panel of expert coaches. In contrast, sub-elite players were less efficient in their selection of critical and non-critical players and were not as adept at assigning a hierarchy of probabilities to likely events. The ability to perceive the most likely pass by an opponent not only focuses the expert’s attention, but considerably reduces the amount of uncertainty within the display, both of which help to guide anticipatory movements and facilitate expert performance.

### Training Perceptual-Cognitive Skill

Researchers have devoted considerable efforts to better understand the specific features and display characteristics that experts utilise to facilitate high-level performance in sport. This has been achieved through a variety of methodological paradigms as well as a range of process tracing measures, such as verbal protocol analysis, eye-movement data, and temporal/spatial occlusion techniques. With a better understanding of the processes governing skilled behaviour, there is substantial interest in finding appropriate training methods to accelerate the acquisition of these perceptual-cognitive skills to effectively shortcut the route to expertise (Williams & Grant, 1999). This seems particularly pertinent since it is widely believed that individuals must partake in at least 10, 000 hours or 10 years of deliberate practice in order to attain expertise within a particular domain (e.g., Ericsson et al., 1993). Although anticipation will improve through experience alone (Abernethy, 1989), sport-specific perceptual training programmes have increasingly been developed as a method of performance enhancement (e.g., Ward, Hancock, & Williams, 2006; Williams, Ward, & Smeeton, 2004). Typically, researchers have attempted to improve anticipation by training advance cue utilisation (e.g., Müller, Abernethy, & Farrow, 2006; Williams & Davids, 1998) for relatively closed-skill situations, such as the penalty kick in soccer (e.g., Williams & Burwitz, 1993; Salvesbergh, Williams, van der Kamp & Ward, 2002). Given the inherent difficulty of implementing a cognitive training intervention within the competitive setting (e.g. for exceptions see; Adolphe, Vickers and Laplante, 1997; Harle and Vickers, 2001) training methods are typically laboratory-based, where perceptual conditions of the real-world setting are closely replicated to maintain some form of ecological saliency. Researchers normally employ video simulations of experts in action to recreate the performer's customary perspective, such as the opponents' view of the return of serve in tennis (e.g., Ward et al. 2002). The important sources of information on which to focus are highlighted, while emphasising the link between these display cues and eventual outcome (Christina, Barresi, & Shaffner, 1990; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; Williams & Burwitz, 1993). Information rich areas have traditionally been determined in a subjective manner, with experts verbally indicating which perceptual cues they focus on when anticipating the intentions of an opponent.

An early training programme was undertaken by Williams and Burwitz (1993), who attempted to identify the specific postural cues used to anticipate the direction of the ball when saving a penalty kick in soccer. A temporal occlusion paradigm was employed to selectively manipulate the duration of the kick that was visible, as skilled and less skilled players predicted which corner of the goal the ball was directed to. Skill-based effects were more apparent at earlier occlusion conditions, with the post-test questionnaire revealing how skilled players extracted information from the run-up, kicking leg, angle of the trunk, and hip position of the penalty-taker, prior to foot-ball contact. These kinematic cues were then used to try and improve novice goalkeepers in a video-based training program. Significant pre to post-test differences in anticipatory performance were observed after 90-minutes of training, when compared to a control group (see also Abernethy, Parks, & Wood, 1999; Singer et al., 1996).

In another penalty-based study, Williams, Ward and Chapman (2003) examined whether anticipation for field-hockey goalkeepers could be improved. An additional aim was to observe whether potential training effects in the laboratory transferred to the competitive setting, using a novel field-based measure of anticipation. Using video simulation, the training group received instruction as to the important information cues underpinning anticipation, which were derived from a previous study involving a comparison of visual search strategies and anticipatory performance in expert and novice field-hockey goalkeepers (see Chapman, 2001). In contrast, the placebo group watched an instructional video concerning field-hockey keeping skills, while the control group received no instruction or training and completed the laboratory and field-based pre and post-tests. Findings demonstrated how participants who underwent the training programme improved their performance beyond that of the placebo and control groups for both the laboratory and field-based tests of anticipation. The study provided further evidence of the practical utility of perceptual training programs whilst making a novel attempt to extend laboratory based findings to a real-world context.

### *Instructional Design in Perceptual Training Programmes*

Having established that anticipation can be improved through perceptual training, more recent studies have endeavoured to find out the most effective and time-efficient way of doing so (Ryu, Kim, Abernethy, & Mann, 2013). Traditionally, instructional design in perceptual training programmes has been mainly explicit, where individuals are given detailed instructions about the specific information sources to look for and attend to in order to develop a particular skill (e.g. Abernethy, Wood and Parks, 1999; Farrow, Chivers, Hardingham and Sachse, 1998). This fits nicely with Anderson's (1982) theory of cognitive skill acquisition, as the prescriptive nature of instruction is thought to accelerate early learning and the formation of specific productions, thereby reducing the time spent searching for relevant information. Declarative knowledge is also thought to provide a structured framework for subsequent knowledge development (Chase & Ericsson 1982). With continued learning, knowledge becomes highly proceduralised and enables complex stimuli to be processed more effectively, leading to faster responses and, potentially, greater resilience under stress (Anderson, 1987; Beilock & Carr, 2001). Although knowledge stored in declarative form and 'if-then' statements may suffice for straight-forward decisions, less prescriptive types of instruction may be more beneficial when training anticipation for the unpredictable nature of sport. Recent instructional design approaches have therefore employed a less informative and more liberated approach where instructions are manipulated to encourage implicit rather than explicit processing of key information (e.g., Smeeton et al., 2005). Guided-discovery is a commonly used method of implicit learning where the aim is to direct attention to critical display features without the provision of any explicit rules to help interpret and use this information (Jackson & Farrow, 2005). In view of the previously discussed constructivism accounts to learning (e.g., Paiget, 1985; Gregory, 1970; Bruner, 1960), the aim of this approach is to facilitate learners in discovering principles for themselves, while affording the opportunity to formulate their own hypotheses of the environment.

For example, Farrow and Abernethy (2002) examined the relative effectiveness of explicit and implicit video-based perceptual training to improve the ability of junior tennis players to anticipate the direction of an opponent's serve. During the training period, the explicit group were clearly instructed about the relationship between specific aspects of the pre-contact service kinematics in the opponent's service action and resultant service direction. In contrast, the implicit group were required to estimate the velocity of each occluded serve, as a means of directing attention to the anticipatory cues without the use of explicit instruction.

Findings revealed a significant improvement in prediction accuracy after the 4-week training intervention for both training groups in comparison to a control group, thereby illustrating the potential utility of less explicit instructional approaches in enhancing anticipation skill.

Colour cueing has also been used as an alternative guided-discovery method to highlight specific perceptual cues in the visual display (e.g., Osborne, Rudrud & Zezoney, 1990; Posner, 1980). For example, Savelsbergh, van Gastel, and van Kampen (2010) attempted to improve the visual search behaviours of inexperienced soccer goalkeepers, to better estimate direction of the ball during a penalty-kick. Participants were divided into three groups and moved a joystick in response to which direction they thought the penalty-kick was directed. The perceptual learning group viewed action sequences containing a moving highlight concerning the key information in the run-up sequence of the kicker, based on previous research (Franks & Harvey, 1997; Savelsbergh et al., 2002, 2005; Williams & Burwitz, 1993). In contrast, a discovery learning group were exposed to the same clips without any highlights, and the control group completed the pre and post-tests. Findings revealed significant changes in the visual search behaviour of the perceptual learning group, as well as earlier initiation of the joystick movement after the intervention. This initiation coincided with the timing of the most important visual information and led to significantly better performance than the other two groups (i.e. more penalties were stopped). Evidence was therefore provided to suggest that guided-discovery techniques using colour cueing is more effective than discovery learning when attempting to improve anticipation in novice soccer goalkeepers.

Researchers have devoted considerable efforts to better understand the specific features and display characteristics that experts utilise to facilitate high-level performance in sport. This has been achieved through a variety of process tracing measures and methodological paradigms, such as verbal protocol analysis, eye-movement data, and temporal/spatial occlusion techniques. As a result, a number of distinct perceptual-cognitive skills have been identified, which are thought to underpin anticipation and decision-making skill. In recent years, there has been increased interest in finding appropriate training methods to facilitate the acquisition of these. The above rundown of the perceptual training literature provides a very brief insight into how researchers have endeavoured to create innovative programs as a means to enhance sporting performance (for reviews, see Causer, Janelle, Vickers, & Williams, 2012; Vine, Moore, & Wilson, 2014; Williams & Grant, 1999; Williams & Ward, 2007). Findings have generally been positive, with a significant body of research accrued to demonstrate how video-based simulation can be used to direct attention to key environmental cues in order to induce meaningful training effects that transfer to the real-world setting (e.g., Williams et al., 2003). For all their potential efficacy however, perceptual training programs are a work in progress, with plenty of research still to be done in order to develop more effective and robust interventions. Most notably, the relative importance of explicit and implicit learning processes in the acquisition of regulatory information has yet to be resolved, and remains a controversial topic (e.g. e.g. Magill, 1998; Beek, 2000; Farrow and Abernethy, 2002). Moreover, and with anticipation shown to be dependent on a range of perceptual-cognitive skills other than advance cue utilisation (e.g., Williams, 2009; Roca et al., 2013), an interesting issue is whether skills such as pattern-recognition and situational assessment (for an exception see Williams, Heron, Ward, & Smeeton, 2004) can also be trained.

### Aims of the Thesis

Although the plethora of literature on perceptual-cognitive skill has proved influential in identifying the important display cues underpinning expert performance, researchers have focussed primarily on relatively closed skills (e.g., penalty kicks, see Savelsbergh, Williams, van der Kamp, & Ward, 2002; McMorris & Hauxwell, 1997) or simple one-on-one/other small-sided (e.g., 3 vs. 3) situations (e.g., see Helsen & Pauwels, 1993; Williams & Davids, 1998). In contrast, there has been very little headway in understanding the specific processes that mediate skilled anticipation in full-sided, open-play sports. In these environments, many researchers consider the ability to recognise patterns of play as the strongest predictor of anticipation in sports such as soccer and hockey (e.g., Abernethy et al., 1994; Abernethy, Baker, & Cote, 2005; Williams & Davids, 1995). Despite expert-novice differences frequently being reported for this particular skill (e.g., Ward & Williams, 2003; Williams & Davids, 1995), relatively little is known about the mechanisms underlying such observations. The primary aim of this thesis was to therefore gain a greater appreciation of the nature of information underlying skilled recognition, and potentially anticipation in team-ball sports. The sport of soccer provides an appropriate vehicle to examine these issues given its complex and rapidly changing environment, as well as the need to pick up information from the elaborate interactions between the ball, team-mates and opponents.

As a brief overview, Chapter 2 presents a series of experiments in an attempt to better identify the specific sources of information skilled performers extract from the visual display when attempting to recognise familiarity in dynamic, structured stimuli. From ascertaining the nature of information underpinning skilled recognition, Chapter 3 examines whether familiarity can still be perceived when only the minimal essential information is presented. Chapter 4 examines the relative importance of both pattern-recognition and advance cue utilisation to anticipation performance. Finally, Chapter 5 implements findings from the previous studies to investigate whether the ability to perceive familiarity may be improved through training and instruction, and the extent to which this may transfer to anticipation performance. Each of these aims are now discussed in greater detail.

**What are the mechanisms underpinning skilled recognition of structured action sequences?**

The point-light technique has proved instrumental to the study of expertise in order to examine the nature of information constrained from the visual display when observing movement (Johansson, 1973, 1976). This approach presents biological information as points of light against a black background, typically achieved by attaching reflective markers to major joints or kinematic landmarks of the individual under observation. Superficial and contextual information within the visual display is removed, which presents movement in its simplest terms (Cutting & Profitt, 1982). In doing so, researchers have demonstrated how individuals are able to recognise the familiar facial features of a friend (e.g., Barclay, Cutting, & Kozlowski, 1998; Peterson and Rhodes, 2003), identify gender on the basis of gait pattern (e.g., Mather & Murdoch, 1994), classify different animal species (Mather & West, 1993) and understand American sign language (Poizner, Bellugi, & Lutes-Driscoll, 1981).

The point-light technique has also been used to examine expertise within a sporting context. For example, Ward, Williams, and Bennett (2002) asked expert and novice tennis players to anticipate the direction of forehand and backhand shots under 'normal' and 'point-light' (PLD) viewing conditions. Findings revealed the experts' superior anticipation performance for the two viewing conditions, while their visual search behaviour remained relatively stable across both conditions in contrast to the novices. It was subsequently concluded that the experts extracted similar sources of information from each viewing condition. More specifically, skilled individuals have been shown to perceive and constrain the relative motion between key anatomical features to determine the intentions of their opponents, rather than extracting information from more superficial features or an isolated area or cue (e.g., Abernethy, Gill, Parks, & Packer, 2001). In fast-ball sports where the ability to predict an opponent's intentions is critical to success, several researchers are in agreement that the perception of relative motion facilitates anticipation, and is therefore a prerequisite for expert performance (e.g., Horn, Williams, & Scott, 2002; Ward, Williams and Bennett, 2002). Despite such findings, the effectiveness of PLDs to identify patterns of interaction between individuals that are commonly observed in in more open, team-based games, is less clear. An interesting question therefore remains as to whether elite players in these sports are able to extract inter-individual relative motion to facilitate the recognition of patterns of play, and thus expert performance.

Seminal work in this area was conducted by Williams, Hodges, North, and Barton (2006) who examined the relative importance of superficial display features and relational information between players when attempting to recognise sequences of play in soccer. Skilled and less skilled players were required to make recognition-based judgments under normal viewing conditions and when sequences of play were converted from film to PLD. In the latter condition, player positions and movements were highlighted as coloured dots against a black background with the playing area represented as white lines, and other contextual information removed. Although players were not as quick or accurate at recognising previously viewed soccer clips in PLD, the decrement in recognition performance was not as profound for the skilled group, and more importantly, a main effect for skill was found across both viewing conditions. Findings therefore suggested that for skilled players, the positions of players on the field of play and the relational information between these features, provides the necessary information for successful recognition performance. This finding fits nicely with the Interactive Encoding Model proposed by Dittrich (1999), which advocates that when viewing stimuli involving interactions between several elements, 'relational information' is central to perceiving and interpreting meaning. Skilled performers initially extract low-level motion information as well as temporal relationships between features, before engaging in high-level processing, where the stimulus presentation is matched with an internal semantic concept or template (Diderjean & Marmeche, 2005; Gobet & Simon, 1996b).

**What are the most important sources of information underpinning skilled recognition in team-based sports?**

Although the relative difference in performance under PLD and standard video conditions helps to determine the extent to which performers depend on superficial display features and/or relations between these features when identifying patterns of play, alternative procedures are required to gain a greater appreciation of the specific features extracted from the visual display during recognition judgments. The spatial occlusion technique offers one approach to addressing this issue. Typically, participants are presented with film sequences where certain display features have been occluded (e.g., racket or arm in tennis). If there is a decrement in performance when a particular cue is occluded, compared to a control condition where a supposedly irrelevant source of information is removed, then the importance of the occluded source of information is highlighted (for a more detailed review, see Williams et al. 1999).

Williams and colleagues (2006 – Experiment 3) attempted to disrupt relational information between display features in full-sided action sequences, to examine whether some players convey more critical information than others when identifying sequences of play in soccer. In line with previous research regarding the importance of central offensive players when attempting to recognise/anticipate an evolving pattern of play (Williams et al., 1993; 1994), these players were occluded from some of the action sequences along with their defensive markers during the recognition phase of the paradigm. An additional control condition whereby two peripheral players and their defensive markers were also occluded, ensured any change in recognition performance was not due to the occlusion procedure itself. Findings revealed no main effect for skill, as skilled players' demonstrated a significant decrement in recognition accuracy when the two central forward players and their defensive markers were occluded, in comparison to the non-occluded film and control conditions. It was subsequently concluded that the relational information between these key players, team-mates and their defensive counterparts may provide critical structural information for effective pattern-recognition in soccer.

Employing complementary process tracing measures, North and colleagues (2009; North, Ward, Ericsson, & Williams, 2011) further examined whether certain players convey more information than others when making familiarity judgments to dynamic soccer action sequences. Skilled and less skilled players were required to identify previously viewed stimuli presented in normal and PLD conditions. Eye-movement data showed how the skilled players recorded a higher number of fixations on central attacking players and made more fixation transitions from the ball to an attacking feature and vice versa, when compared with less skilled players. Subsequent verbal report analysis gathered after each trial, revealed how skilled players made significantly more verbalisations involving the movements of attacking players 'off the ball' than less skilled players, with the central offensive players being particularly important for the skilled players when sequences were presented in PLD. In line with the work of Williams et al. (2006), North et al. (2009; 2011) provided evidence to suggest that the ability to pick up relational information between a few key features, notably the central attacking players, is crucial when attempting to identify familiarity within dynamic sequences of play in soccer.

While the aforementioned research has undoubtedly broadened our understanding of the underlying mechanisms facilitating pattern-recognition skill in soccer, two important questions remain unanswered. Firstly, the exact nature of the relational information between key features has yet to be determined. To this end, it is unclear whether familiarity is perceived through reference to the locations or positions of these features, or via reference to the relative or absolute motions of key features. Although it is envisaged that relative motion information between these players constrains skilled familiarity judgments, this has yet to be addressed empirically by manipulating access to motion information within the presented stimuli. Consequently, Chapters 2 and 3 investigate this issue in greater detail. A secondary point of interest pertains to the key features or combination of features that are important when making familiarity-based judgments to interactive soccer displays. In this regard, the potential importance of other players in conjunction with the central forwards is an interesting question that has yet to be adequately addressed in the literature. This is examined further in Chapters 2 and 3 by employing a spatial occlusion procedure to determine whether recognition performance deteriorates when various combination of players are occluded from the visual display.

**What is the relative influence of relational and postural information on anticipation skill?**

Despite its perceived importance to high-level performance (e.g., Abernethy et al., 2005), pattern-recognition is not the only perceptual-cognitive skill constraining anticipation performance in team-ball games, such as soccer and hockey. Researchers have demonstrated how anticipation in these sports is dependent on a range of perceptual-cognitive skills, yet there have been very few reported attempts to examine how these skills interact with each other in a dynamic and evolving manner to facilitate anticipation in the competitive setting (cf. Williams & Ward, 2007). To this end, a reductionist approach has generally been adopted, employing paradigms that examine each skill in isolation from the others (e.g., North et al., 2009; Williams & Burwitz, 1993; Ward & Williams, 2003). This seems somewhat counterintuitive given the relative importance of each perceptual-cognitive skill is likely to vary as a function of the constraints of the task environment, situation, and player (Newell, 1986; Williams, 2009; Roca et al., 2013) (see Figure 1.1).

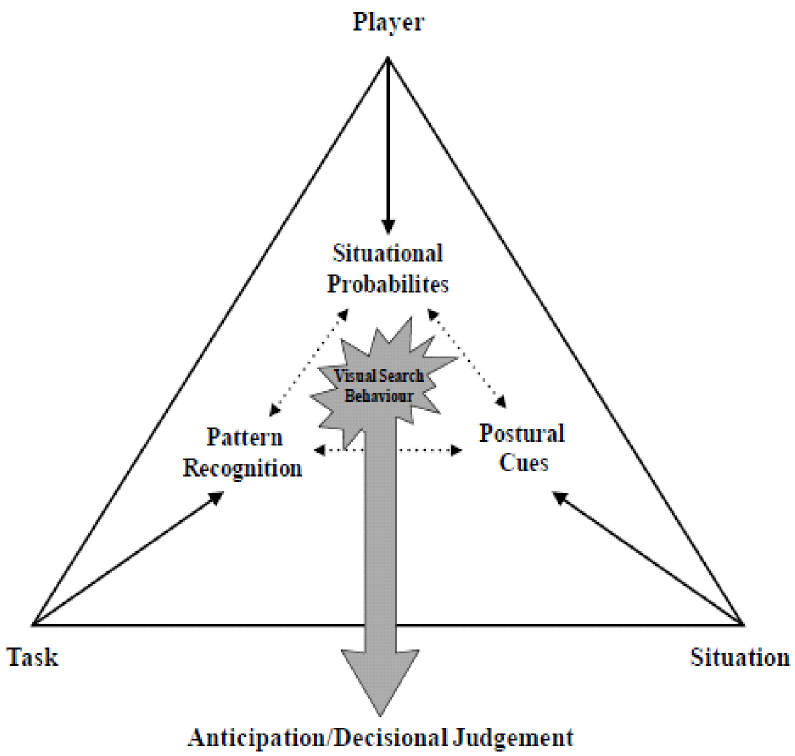


Figure 1.2: The interactive relationship between the various perceptual-cognitive skills and constraints related to task, situation, and player when making anticipation judgments.

*(Reprinted and adapted from Progress in Brain Research, 174, Williams. A. M., Perceiving the intention of others: How do skilled performers make anticipation judgments? p. 80, 2009).*

With regards to task constraints, very few researchers have explicitly manipulated these to gain a greater appreciation of how the various perceptual-cognitive skills interact to constrain anticipation judgments (Williams & Ericsson, 2005). Typically, researchers have examined anticipation performance and process tracing measures as a function of the number of players involved in the passage of play, the proportion of attackers and defenders, and the participant's specific functional role or goal (defender vs. attacker) (e.g., Vaeyens et al., 2007a,b). In a recent exception, Roca and colleagues (2013) examined the effect of manipulating ball distance relative to the performer on anticipation and decision-making skill in soccer. Using the halfway line as a reference point, skilled and less skilled players were presented with life-sized 11 vs. 11 film sequences from both a near and far viewing perspective, while complementary eye-movement recording and verbal protocol analysis were collected. Skill-based differences in anticipation and decision-making skill were underpinned by differences in task-specific search behaviours and thought processes. Moreover, the perceptual-cognitive skills underpinning these skill-based differences were shown to differ in importance across the two task constraints.

With notable methodological amendments, Chapter 4 in the current thesis builds directly upon this work to further explore how the different perceptual-cognitive skills interact during anticipation performance as a function of the constraints of the task environment. More specifically, by presenting action sequences in video and PLD across the near and far viewing perspectives, a greater appreciation for the importance of relational and postural information to anticipation can be obtained. It is also envisaged that such manipulations will provide further evidence for the potential importance of pattern-recognition skill to anticipation, which remains a somewhat contentious issue. To this end, several researchers argue that the ability to recognise patterns of play is a central component of anticipation skill in team sports (e.g., Abernethy et al., 1994; 2005; Williams & Davids, 1995; Williams et al., 2006), whereas others propose that it is simply a by-product of extended task exposure and not a constituent of expertise (e.g., Ericsson & Lehmann, 1996).

**Can pattern-recognition skill be trained, how, and does this transfer to anticipation?**

As previously discussed, perceptual training programmes are increasingly been used to develop advance cue utilisation in an attempt to enhance sporting performance (e.g., Williams & Burwitz, 1993). Despite its perceived importance to anticipation (e.g., Williams & Davids, 1995), there is a paucity of research examining whether pattern-recognition skill can be improved through instruction (Ward & Williams, 2003; Williams & Hodges, 2005). This is hardly surprising however, as to train any perceptual-cognitive skill, researchers must be aware of the processing mechanisms that underpin it. Consequently, and with Chapters 2 and 3 of the current thesis exploring the essential information underlying skilled pattern-recognition in soccer, Chapter 5 examines whether it can be trained. In line with the continued debate as to the most effective method of directing the learner's attention to critical sources of information within the visual display (e.g., Magill, 1998), a secondary aim is to compare the relative effectiveness of various instructional designs in developing pattern-recognition skill. A final aim of Chapter 5 is to further explore the potential relationship between pattern-recognition and anticipation. In view of Chapter 4, many researchers argue that the ability to recognise patterns of play is a central component of anticipation skill in team sports (e.g., Abernethy et al., 1994; 2005; Williams & Davids, 1995; Williams et al., 2006). In contrast, others believe that while it may provide a reasonable indicator of the knowledge held by performers, it is not directly related to, nor predictive of, anticipation skill (e.g., Ericsson & Lehmann, 1996). To this end, an interesting question remains as to whether potential training effects for pattern-recognition transfer to anticipation performance. In Chapter 6, the findings from this programme of work are collated in order to provide a clear and concise summary of both the theoretical and applied implications of the thesis. Future research directions are discussed alongside potential limitations of the programme of work.

# Chapter 2: Identifying the Mechanisms Underpinning Recognition of Structured Sequences of Action

## Abstract

In this chapter, three experiments are presented to identify the specific information sources that skilled participants use to make recognition judgements when presented with dynamic, interactive stimuli. A group of less skilled participants acted as controls. In all experiments, participants were presented with filmed stimuli containing structured action sequences. In a subsequent recognition *phase, participants were presented with new and previously seen stimuli and were required to make judgements as to whether or not each sequence had been presented earlier (or were edited versions of earlier sequences). In Experiment 1, skilled participants demonstrated superior sensitivity in recognition when viewing dynamic clips compared with static images and clips where the frames were presented in a non-sequential, randomised manner, implicating the importance of motion information when identifying familiar or unfamiliar sequences. In Experiment 2, normal and mirror-reversed sequences are presented in order to distort access to absolute motion information. Skilled participants demonstrated superior recognition sensitivity, but no significant differences were observed across viewing conditions, leading to the suggestion that skilled participants are more likely to extract relative rather than absolute motion when making such judgements. In Experiment 3, relative motion information was manipulated by occluding several display features for the duration of each film sequence. A significant decrement in performance was reported when centrally located features were occluded compared to those located in more peripheral positions. Findings indicate that skilled participants are particularly sensitive to relative motion information when attempting to identify familiarity in dynamic, visual displays involving interaction between numerous features.



**Keywords**: *Expertise, Pattern-recognition, Relative motion*, *Absolute motion*

The ability to recognise visual stimuli is important in several tasks such as engaging in military combat (Williams, Ericsson, Ward, & Eccles, 2008), undertaking diagnostic imaging tasks (Nadine & Kundle, 1987), driving a car (McKenna & Horswill, 1999), playing board games (Charness, Reingold, Pomplun, & Strampe, 2001), and in competitive sport (Williams et al., 2006). This ability to recognise familiarity may be particularly important in tasks where there is considerable time pressure on performance, requiring individuals to selectively attend to only the most relevant sources of information, while disregarding irrelevant or non-regulatory cues. These situations may be particularly important in law enforcement, in military combat, and in sport and games such as speed chess, where the ability to detect familiarity early in an evolving sequence of action may provide a significant advantage over an opponent who is less effective at making such judgements. Several researchers have suggested that the ability to recognise familiarity may be an important precursor of anticipation in these types of situations (e.g., Cañal-Bruland & Williams, 2010; Chabris & Hearst, 2003; North et al., 2009).

Although the need to perceive familiarity may be crucial in many domains, as yet there have been relatively few attempts to identify how such judgements are made. More specifically, only a few published reports outline the mechanisms underlying skilled perception or the specific information that performers pick up when making such judgements. In this paper, three experiments are reported to examine these issues. The sport of soccer is used as a vehicle given its dynamic nature and the complex interaction between numerous interactive features that are free to move independent of one another. Film clips involving structured, offensive sequences of play are presented in order to examine recognition performance under different experimental conditions. Skilled and less skilled participants were examined to determine whether they process and recognise such stimuli as a function of specific features such as the locations of isolated or superficial display features, or whether it is the relative or absolute motions between features that are essential when making such familiarity-based judgements.

In Experiment 1, the importance of motion information in recognition judgements is tested by comparing performance when viewing dynamic sequences, static/still images, and footage where the individual frames of the film sequence are presented randomly in a non-sequential order. The static/still images present no motion information yet access to relational information involving player locations and more superficial surface features such as the colour of players' uniforms and the condition of the field of play remains present. The condition in which individual frames are viewed in a random order distorts access to motion information and ensures that the amount of information presented remains consistent with the normal dynamic trials. The static condition differs from the random and dynamic condition in regard to both the absence of motion information and the amount of information presented over the duration of a trial. In Experiment 2, sequences of play are mirror-reversed such that the relational information between features, the relative motions between them, and superficial surface features do not differ, but the absolute motion (i.e., directional movement of individual features such as the ball) is reversed. In Experiment 3, a more subtle manipulation is used by removing certain features from the action sequences in order to disrupt access to more localised relative motions, while ensuring that superficial surface features, and to a lesser extent the locations of players, remain consistent. The overall aim was to identify the processing mechanisms and the specific sources of information used when engaging in laboratory tests designed to examine recognition performance in dynamic, interactive, temporally constrained domains.

The recognition paradigm is rooted in cognitive psychology. Goldin (1978) reported that recognition of chess pieces was enhanced after players had chosen a move (i.e., a semantic task representative of chess playing) as opposed to counting the number of chess pieces (i.e., a superficial unrelated task). It was concluded that the processing of meaningful relations enhanced the accuracy of recognition. Allard and colleagues (1980) were the first to use this paradigm in sport. They presented skilled and less skilled basketball players with a series of static slides showing either structured (images sampled from organised match play) or unstructured (images showing teams warming up or sampled from breaks in play) scenes, some of which had been presented to participants in an earlier viewing film and others that were novel. Participants were required to make a familiarity-based recognition judgement for each scene. Skilled basketball players demonstrated superior recognition accuracy on structured stimuli only. This finding has been replicated across numerous sports such as field hockey (Smeeton, Ward, & Williams, 2004), American football (Garland & Barry, 1991), and soccer (Williams & Davids, 1995). Only recently have researchers started to identify the specific information that skilled performers use when making successful recognition judgements. Williams et al. (2006, Experiment 2) examined the contributions of superficial low-level surface features (e.g., shirt colour, body cues, or environmental or pitch conditions) and the relational information between these features (e.g., the positions or relative orientation of players) when making recognition judgements. Skilled and less skilled soccer players were required to make recognition judgements to sequences presented in both film and point-light display (PLD) formats. In the latter condition, the locations and movements of players were presented as points of light against a black background, along with the position of the ball and an outline of the field of play, thereby removing access to superficial display features while preserving the relational information between players. The skilled performers reported better recognition performance under both viewing conditions, with their superiority over less skilled counterparts being maintained under the PLD condition. In contrast, the less skilled players showed a significant decrement in performance under PLD compared to normal viewing conditions. Skilled participants detect familiarity based upon structural relations (e.g., positions of features or their relative orientations) and the higher order predicates they convey (e.g., tactical and/or strategic significance; cf., Gentner & Markman, 1997). According to the

Interactive Encoding Model proposed by Dittrich (1999), when viewing such sequences skilled performers initially extract information from the positions and temporal relationships between features and then match this stimulus representation with an internal semantic concept or template (cf., Charness et al., 2001; Didierjean & Marméche, 2005). A related proposal is the notion that skilled individuals develop elaborate task-specific retrieval structures, which aid the identification of future outcomes (Ericsson & Kintsch, 1995; Ericsson, Patel, & Kintsch, 2000). Superior retrieval is therefore achieved through better indexing and organisation of information at encoding.

In previous work, Williams et al. (2006, Experiment 3) edited the film sequences such that the central attacking players were occluded during the recognition phase in an attempt to remove access to some of relational information between players. A significant decrement in the recognition accuracy of skilled participants was observed in the occluded conditions, suggesting that the relationships between central attackers and other features provide the critical structural information. Subsequent research using complementary methodologies, such as eye movement recording and verbal protocol analysis, reinforced the findings and conclusions reported by Williams and colleagues (e.g., North et al., 2009; 2011; Williams et al., 2006; Williams & North, 2009). Skilled perception is believed to combine low and high-level processes. First, participants extract positional information and the temporal relationships between these features before matching this stimulus representation with an internal semantic concept or template developed through extended practice and engagement in the domain (see Didierjean & Marméche, 2005; Dittrich, 1999; Dittrich & Lea, 1994; Gobet & Simon, 1996a). In contrast, less skilled performers lack experience within the domain, and, consequently, they will not have developed these high-level semantic concepts and are likely to be impaired in their ability to attribute meaning to this relational information. Less skilled performers will adopt a less sophisticated, low-level processing strategy focusing on more discrete or superficial elements and not on relational information (Dittrich, 1999). This literature provides evidence that skilled performers encode displays involving numerous features as a series of relationships arising in the final few moments preceding a critical event (North & Williams, 2008). However, it is not clear whether these relationships are encoded through motion information (i.e., relative, absolute, or common motion) or positional information, and, consequently, the current chapter attempts to shed more light on this issue.

## Experiment 1

In this experiment, a recognition paradigm is employed to examine whether skilled participants perceive familiarity in the display through reference to the locations or positions of display features or via reference to the motions of these features (i.e., the players and/or the ball). In the initial viewing phase, participants are presented with structured stimuli, showing dynamic film footage occluded at the final frame prior to an attacking pass being made. In a later recognition phase, participants are presented with further clips, some of which were presented during the earlier viewing phase and others that are novel. In addition, the action sequences were edited to manipulate access to motion information by creating three different types of clips: dynamic, static, and randomised. Participants are required to decide whether or not they had seen each of these sequences (edited or otherwise) in the earlier viewing phase. The sensitivity of participants' recognition judgements and their response bias were taken as measures of performance.

It was predicted that skilled participants would be more accurate when recognising dynamic than both static and randomised stimuli (cf., Williams et al., 2006). In the static clips, motion is removed, and less information (only a single frame) is presented than in the dynamic and randomised sequences. The randomised sequences present the same amount of information as in the dynamic sequences, but in the former condition access to motion information is distorted. In the randomised clips, the different frames of action are presented in a non-sequential, random manner, rather than in the same sequential order as that employed in the dynamic condition. It was envisaged that both the amount of information and access to motion cues are crucial when making familiarity-based judgements and that, consequently, the skilled players would perform better in the dynamic than in the randomised condition. In contrast, it was predicted that the less skilled participants would rely on superficial display features when encoding a display and that, consequently, there would be no differences in performance between the static, dynamic, and randomised conditions for this group. Although less skilled participants may attempt to extract some relational information based on the positions of players, when compared to skilled players they have less elaborate templates/cognitive representations to interpret the stimuli in a meaningful manner. Consequently, less skilled performers are likely to focus their attention on identifying any distinctive surface features (e.g., colour of players' uniforms, environmental conditions) present within the display.

## Method

### Participants

A total of 10 skilled and 10 less skilled male players participated. Skilled participants (*M* age = 20.30 years, *SD* = 1.06) had previously played at a professional club's Academy and/or were currently playing at a semi- professional level, and all played in defensive positions. These participants had been playing soccer competitively for an average of 13.00 years (*SD* = 2.45). In contrast, less skilled participants (*M* age = 21.60 years, *SD* = 3.50) only played soccer at a recreational or amateur level and had been participating for an average of 11.60 years (*SD* = 4.14). In all three experiments presented in this chapter, participants reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of Liverpool John Moore's University. Participants provided informed consent and were free to withdraw at any stage.

### Test Stimuli

Participants were presented with two separate films of test stimuli: a viewing film and a recognition film. The films both contained structured offensive sequences of play. The stimuli were taken from matches involving the reserve or second teams of professional clubs and did not include any matches involving the participants or players with whom they were familiar. The sequences were filmed using a fixed, tripod-mounted camera (Canon XM-2, Tokyo, Japan) in an elevated position (approximate height 9-metres) behind (approximate distance 15-metres) the goal. The camera did not zoom or pan during recording. This camera position ensured that the entire field of play was visible and that information from wide areas of the field of play was not excluded. The action sequences were filmed from as close as possible to a central defender's position in the game, with all patterns of play emerging in the direction of the viewer. This viewing perspective has been shown to accurately capture expert performance (see Ripoll, Petit, & Le Troter, 2005), and construct validity has been established for the use of such clips in previously published reports (e.g., North et al., 2009, 2011; Ward & Williams, 2003; Williams et al., 2006). All sequences of play involved a number of passing manoeuvres mostly commencing in the defensive half of the pitch and ending with a pass being made into the offensive area of the pitch. Three expert soccer coaches independently rated each sequence as high or low in structure using a Likert-type scale from 0 to 10 (0 being very low in structure, 10 being very high in structure). The clips deemed high in structure were those that were viewed by the coaches to be most representative of the typical offensive sequences observed in match-play. Only sequences with a mean rating of 7 or above were included in the experiment. Only those clips in which there was complete agreement between coaches were used in the experiment. A still-frame from a typical film sequence is shown in Figure 2.1.

Figure 2.1: The viewing perspective presented in the three experiments.

The viewing film contained 54 dynamic action sequences, each of which was 3-seconds in length. During this phase, participants were simply instructed to watch the clips with no response required. The recognition film contained 54 sequences, 36 of which had been presented previously in the viewing phase and 18 that were novel. Of the clips that had been presented previously, 12 were dynamic film sequences, 12 presented a static image of the last frame, and 12 involved dynamic sequences where the frames were presented in a non-sequential, random order. Of the 18 clips that were novel, 6 were dynamic, 6 were static, and 6 were randomised. The dynamic clips were the same as those in the viewing phase, where a 3-second attacking sequence was occluded when a pass or shot at goal was about to be made. In contrast, the static clips showed only the final frame prior to an attacking pass being made for 3-seconds. The randomised clips showed individual frames from a 3-second dynamic sequence presented in non-sequential, random order. A 5-second inter-trial interval was employed to allow participants sufficient time to make a response and prepare for the next clip. The clips were presented in a random order that was kept constant across participants.

### Apparatus

The viewing and recognition films were presented using a DVD player (Panasonic, DMR-E50, Osaka, Japan) and projector (Sharp, XG-NV2E, Manchester, UK) with images being presented onto a 9 × 12″ screen (Cinefold, Spiceland, IN, USA) at a rate of 25 frames per second with XGA resolution. The clips were edited using video-editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA, USA).

### Procedure

Participants were tested individually and sat in a chair a distance of 3-metres from the projection screen such that the image subtended a viewing angle of approximately 40-degrees. During the viewing phase, participants were informed that they would be presented with a series of film clips from soccer matches showing sequences of play. Participants were informed that each clip lasted 3-seconds and would show an attacking pattern of play leading to a pass into an offensive area, although the action would be occluded at the final moment before this event occurred. Participants were instructed to watch the clips as if playing in the match, adopting the perspective of a central defender.

After presentation of the viewing film, there was a 10-min break during which participants completed a practice history questionnaire. Participants were then asked to view a second series of clips, some of which had been presented previously in the viewing film and others that were novel. They were informed that some of the clips originally presented would now be shown as edited versions of the same sequence in the recognition phase. Participants were instructed to watch each trial for its entire duration and then make a decision whether or not that clip had been presented previously in the viewing phase. Since several clips had now been edited, participants would technically be correct to indicate that these clips were different to those previously presented in the viewing phase and were thus novel. As such, participants were informed that their task was to respond “yes” to action sequences they believed were edited versions (static/random) of those presented earlier in the viewing phase and "yes" to those seen earlier, but not edited (dynamic). In contrast, they were instructed to respond "no" to video clips they believed to be novel and were therefore not presented in the viewing phase. A brief familiarisation procedure was employed during which participants were shown three examples of each viewing condition. Participants responded using pen and paper.

**Data Analysis**

Signal detection measures of sensitivity (*d′*) and response bias (*c*) were used to measure recognition accuracy (Green & Swets, 1966). The data for *d′* and *c* were analysed separately using a mixed design two-way analysis of variance (ANOVA) in which the between-participants factor was skill (skilled vs. less skilled), and the within-participants factor was display (dynamic vs. static vs. randomised). The assumption of normality was satisfied as determined using a Shapiro–Wilks test. Partial eta squared ($_p^2$) values are provided as a measure of effect size. Cohen's *d* measures are reported where two means are compared. The alpha level for significance was set at $p < .05$.

## Results

A summary of the descriptive statistics for all experiments is presented in Table 2.3. The analysis of *d*' revealed a significant Skill x Display interaction, $F_{2, 36} = 3.58$, $p < .01$, $_p^2 = .29$. Skilled participants were more sensitive in their recognition judgments for dynamic ($M = 1.50$, $SD = .52$) compared to static ($M = -.43$, $SD = .51$) and randomised ($M = .42$, $SD = .75$) clips, $d = 3.75$ and 1.67 respectively. In contrast, less skilled participants did not differ in recognition sensitivity across dynamic ($M = .14$, $SD = .55$), static ($M = -.10$, $SD = .94$), and randomised ($M = 0$, $SD = .75$) clips, $d = .31$ and .21 respectively. This interaction is illustrated in Figure 2.2. A main effect for skill was observed, $F_{1, 18} = 10.10$, $p < .01$, $_p^2 = .36$. Skilled participants ($M$ = .49, $SD$ = .90) were more sensitive in distinguishing previously seen from novel stimuli than their less skilled counterparts ($M$ = .02, $SD$ = .70), $d$ = .54. Finally, there was a significant main effect for display, $F_{2,\,36} = 12.22$, $p < .001$, $_p^2 = .40$. Bonferroni-corrected pairwise comparisons showed participants were more sensitive in their recognition judgments to dynamic clips than they were to static ($d$ = 1.32) and randomised ($d$ = .75) conditions, $p$'s <.05. There was no significant difference for response sensitivity between static and randomised clips, $p > .05$.

The analysis of $c$ showed no main effect for skill, $F_{1,\,18} = 3.14$, $p > .05$, $_p^2 = .15$ or display type, $F_{2,\,36} = .62$, $p > .05$, $_p^2 = .03$. The Skill x Display interaction was not significant, $F_{2,\,36} = .36$, $p > .05$, $_p^2 = .02$.

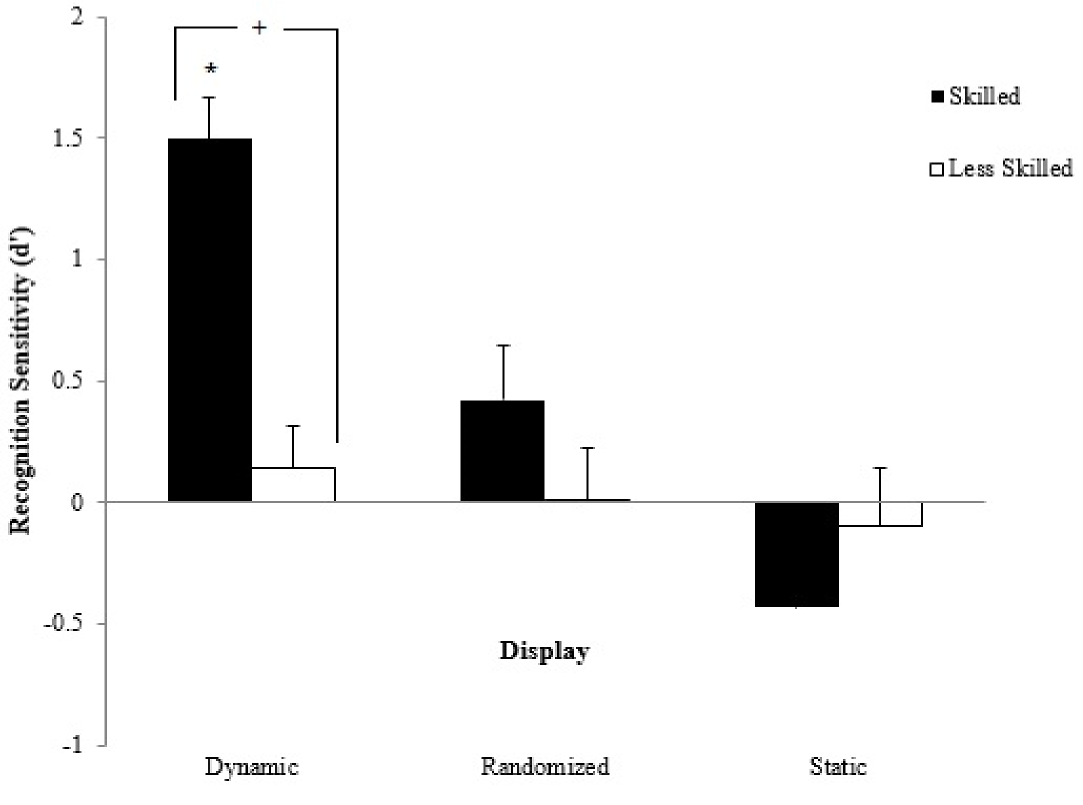


Figure 2.2: The Skill x Display interaction (with $SD$ bars) for recognition sensitivity in Experiment 1. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

## Discussion

This experiment examined whether skilled participants perceive familiarity within a display by encoding display features and their positions or by perceiving motion information between these features. Although initial reports suggest that skilled performers perceive and process displays involving numerous elements as relational information (North et al., 2009; Williams et al., 2006), it has yet to be determined whether this relational information is picked up from positional or motion information. Participants were presented with a series of structured displays either as dynamic playing patterns or as static images showing the final frame of an attacking sequence. Moreover, participants were presented with stimuli that showed a series of randomly ordered individual frames to control for the amount of information that was presented in the dynamic sequences. It was predicted that skilled performers would demonstrate more sensitive recognition performance when viewing dynamic sequences rather than static slides. If skilled performance was underpinned by the perception of motion rather than the amount of information presented in dynamic sequences, then skilled participants would demonstrate superior recognition sensitivity for dynamic stimuli in comparison to clips where motion information was disrupted by presenting frames of action in a non-sequential, randomised manner. Less skilled participants were expected not to differ in recognition sensitivity across the dynamic, static, and randomised stimuli. As predicted, skilled participants recorded more sensitive recognition performance when viewing sequences presented in dynamic ($M$ = 1.50) rather than static ($M$ = 0.43) and randomised format ($M$ = 0.42), $d$ = 3.75 and 1.67, respectively. The observed $d'$ values demonstrate that skilled participants are much more sensitive when making recognition judgements in response to dynamic rather than static or randomised stimuli. Skilled participants are able to access the motion information maintained in dynamic sequences in order to perceive meaning and structure when making recognition decisions. The Skill × Display interaction and the descriptive values for $d'$ provide evidence to support the notion that having access to motion information present in dynamic sequences is more important when making recognition judgements than the overall amount of information presented. It appears that skilled participants perceive the relational information mainly as a function of motion information. At this stage, it is not possible to ascertain whether this motion information is extracted from the relative motions between players or the absolute motion of one or more features (Hill & Pollick, 2000).

It was hypothesised that less skilled participants would not differ in sensitivity across the dynamic, static, and randomised conditions. It was envisaged that they would process displays on the basis of superficial display information that was maintained across all conditions. The results reveal that, as predicted, there were no significant differences in recognition sensitivity for less skilled participants across the viewing conditions. A difficulty is that the overall level of performance for the less skilled participants was very low, as illustrated by the $d'$ values presented in Figure 2.2. One possible explanation for the low $d'$ scores exhibited for the less skilled participants across all conditions may be that their relatively impoverished cognitive knowledge structures makes it very difficult for them to encode and store information during the initial exposure when compared to their skilled counterparts. Subsequent memory-based judgements are therefore impaired as the participants are forced to guess rather than to make judgements against information stored in memory. An alternative explanation is that the recognition paradigm methodology may not be sufficiently sensitive; a notion discussed further in the General Discussion.

Table 2.3: The mean recognition sensitivity scores and criterion values for skilled and less skilled participants across the three experiments.

| | *Experiment 1* | | | | *Experiment 2* | | | | *Experiment 3* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Participant group* | *Dynamic* | *Randomized* | *Static* | *Overall* | *Normal* | *Reversed* | *Overall* | *Condition 1* | *Condition 2* | *Condition 3* | *Condition 4* | *Overall* |
| Skilled *d'* | 1.50 | 0.42 | −0.43 | 0.49 | 0.51 | 0.71 | 0.61 | 1.44 | 0.35 | 0.26 | 1.15 | 0.80 |
| | (0.52) | (0.75) | (0.51) | (0.90) | (0.55) | (0.45) | (0.05) | (0.64) | (0.69) | (0.79) | (0.46) | (0.81) |
| Less skilled *d'* | 0.14 | 0 | −0.10 | 0.02 | −0.02 | 0.12 | 0.05 | −0.01 | 0.19 | 0.07 | 0.59 | 0.21 |
| | (0.55) | (0.75) | (0.94) | (0.70) | (0.38) | (0.40) | (0.39) | (0.32) | (0.53) | (0.39) | (0.82) | (0.58) |
| Overall *d'* | 0.82 | 0.21 | −0.26 | 0.26 | 0.24 | 0.42 | 0.33 | 0.71 | 0.27 | 0.17 | 0.87 | 0.51 |
| | (0.87) | (0.76) | (0.76) | (0.89) | (0.53) | (0.51) | (0.52) | (0.89) | (0.60) | (0.61) | (0.71) | (0.76) |
| Skilled c | .11 | .08 | .08 | .04 | −.16 | .10 | −.03 | −.15 | .44 | −.20 | .29 | .09 |
| | (.42) | (.22) | (.39) | (.36) | (.40) | (.39) | (.41) | (.24) | (.38) | (.52) | (.27) | (.46) |
| Less skilled c | −.22 | −.05 | −.20 | −.16 | −.31 | −.07 | −.19 | −.30 | .27 | −.29 | .06 | −.07 |
| | (.51) | (.49) | (.39) | (.47) | (.16) | (.24) | (.23) | (.29) | (.44) | (.39) | (.45) | (.47) |
| Overall c | −.06 | .02 | −.14 | −.06 | −.23 | .01 | −.11 | −.23 | .35 | −.24 | .17 | .01 |
| | (.49) | (.39) | (.39) | (.43) | (.31) | (.33) | (.34) | (.28) | (.43) | (.48) | (.40) | (.47) |

Note: *d'* = recognition sensitivity. *c* = response bias. Standard deviations in parentheses.

## Experiment 2

In Experiment 1, data was presented to suggest that skilled participants rely on motion information when making recognition judgements. However, the specific nature of this motion information has yet to be ascertained. Cutting and Profitt (1982) differentiated between three different types of motion information; namely, absolute, common, and relative motion. Absolute motion describes the motion of a single element in a configuration relative to the person perceiving this information, whereas common motion describes the motion common to all elements in the configuration relative to the perceiver. Finally, relative motion refers to the motion of all the elements in the configuration relative to each other.

Although the relative importance of these three sources of motion information has been examined to some degree in the literature on observational learning and modelling (e.g., see Breslin, Hodges, Williams, Curran, & Kremer, 2005; 2006; Hodges, Williams, Horn, & Breslin, 2007), there have been no previous attempts to explore the relative importance of each source when making familiarity-based judgements in the area of perceptual–cognitive expertise. The majority of researchers have suggested that skilled participants extract relative motion rather than absolute or common motion information when making these types of judgement (e.g., North et al., 2009, 2011; Williams et al., 2006), but this issue has yet to be addressed directly by manipulating access to the different types of motion information.

In the context of structured sequences of play in soccer, it is very difficult to manipulate common motion information since the direction of play is always towards or away from the goal (i.e., up and down the pitch). In contrast, access to absolute motion may potentially be distorted by presenting clips in the recognition phase as mirror-reversed images of those sequences presented earlier in the viewing phase. In this mirror-reversed condition, the relative motions between players and their common motion remain constant, yet the absolute motion of key features is reversed, such as the direction of the pass or the runs of a player about to receive the ball. For example, in the initial viewing phase, an offensive sequence of play that ends with a pass being made to the right-hand side of the field of play would be replaced in the viewing phase by a sequence ending with a pass to the left side of the pitch. In this latter example, the common motion (i.e., movement towards the near end of the pitch) and the relative motions between display features do not differ, whereas the absolute motion of each individual feature differs from that presented originally. In this experiment, film sequences are mirror-reversed in the recognition phase in order to ascertain whether this manipulation leads to a decrement in response sensitivity in skilled and less skilled participants. If skilled participants rely on absolute motion information when making familiarity-based judgements, a decrement in performance is predicted in the reversed condition compared to when viewing the normal (i.e., non-reversed) images. In contrast, the less skilled participants were expected not to differ in their performance across the two conditions given their reliance on more superficial display features rather than motion information when making these types of judgement.

## Method

### Participants

A total of 10 skilled and 10 less skilled male soccer players participated. None of the participants had taken part in Experiment 1. The skilled players (*M* age = 21.6 years, *SD* = 5.19) had previously played at a professional club's Academy and/or were currently playing at a semi-professional level, and all played in defensive positions. Participants had been playing soccer competitively for an average of 13.60 years (*SD* = 3.60). In contrast, less skilled players (*M* age = 20.50 years, *SD* = 1.58) had played soccer at a recreational or amateur level only, typically for around 11.40 years (*SD* = 3.40). All participants reported normal or corrected-to-normal levels of visual function.

## Test Stimuli

Participants were presented with separate films of test stimuli involving a viewing phase and recognition phase, respectively. The action sequences were taken from a similar sample of matches to that used in Experiment 1. These matches were filmed from the same viewing perspective and using the same equipment as that in Experiment 1. The film sequences were made up of structured trials only and were chosen using the criteria and selection process outlined in Experiment 1.

The viewing phase included 60 film clips each involving 3-seconds of dynamic action, followed by an inter-trial interval of 5-seconds. The recognition phase contained 40 clips taken from the viewing phase and 20 new action sequences that had not been seen previously by the participants. Of the 40 clips that had previously been presented, 20 were manipulated using software (Final Cut Pro 7, Apple, Cupertino, California, USA) that enabled the film to be mirror-reversed, while the other 20 remained exactly the same as they were in the viewing phase. The entire filmed image was reversed, creating a mirror image, with features that were previously on one side of the display now presented on the other. Of the 20 additional clips that had not previously been presented, 10 were reversed in the same way, whereas the remaining 10 were not edited.

## Apparatus and Procedure

The apparatus used to present the film clips and the procedure employed were the same as those in Experiment 1. However, participants were instructed that some of the clips originally presented in the viewing phase would now be shown as mirror-reversed images of the same sequence in the recognition phase. Since several clips had now been reversed, participants would technically be correct to indicate that these clips were different to those previously presented in the viewing phase and were thus novel. As such, participants were informed that their task was to respond “yes” to action sequences that they believed were reversed versions of those presented earlier in the viewing phase and “yes” to those seen earlier, but not reversed. In contrast, they were instructed to respond “no” to video clips that they believed to be novel and were therefore not presented in the viewing phase. A brief familiarisation procedure was employed during which participants were presented with five examples of clips under normal and reversed viewing conditions, respectively.

### Data Analysis

The dependent measures and analysis procedures were the same as those in Experiment 1, except in this experiment the display condition compared normal versus reversed clips.

## Results

The analysis of *d*' revealed a significant main effect for skill, $F_{1, 18} = 18.08$, $p < .001$, $_{p}^{2} = .50$. Skilled participants (*M* = 0.61, *SD* = .50) were more sensitive in their recognition judgments than less skilled participants (*M* = .05, *SD* = .39), *d* = 1.25. The Skill x Display interaction, $F_{1, 18} = .04$, $p > .05$, $_{p}^{2} = .002$, and the main effect for display, $F_{1, 18} = 1.3$, $p > .05$, $_{p}^{2} = .07$, were not significant. The recognition sensitivity and criterion scores for skilled and less skilled participants across the two conditions are presented in Table 2.3.

The analysis of *c* revealed a significant main effect for display, $F_{1, 18}$, = 9.78, $p <.05$, $_{p}^{2} = .35$. Participants showed a significantly lower criterion threshold, and hence a bias toward responding 'yes', for normal (*M* = -.23, *SD* = .31) than reversed (*M* = -.11, *SD* = .36) stimuli, *d* = .36. The Skill x Display interaction, $F_{1, 18} = .01$, $p > .05$, $_{p}^{2} = .001$, and the skill main effect, $F_{1, 18} = 1.79$, $p > .05$, $_{p}^{2} = .09$, were not significant.

## Discussion

This experiment examined whether skilled participants perceive familiarity within a display by picking up absolute motion information from one or more display features or by perceiving relative motions between features. Images were mirror-reversed such that the relative motions between features and the common motion of all features presented in the film sequences did not differ, whereas the absolute motion of the key features would be different (i.e., reversed). It was predicted that the skilled participants would show a marked decrement in performance if they recognised clips based on absolute rather than on relative or common motion. In contrast, it has been reported previously (e.g., North et al., 2009, 2011; Williams et al., 2006) that less skilled participants rely on more superficial display features rather than motion information, and so when making recognition judgements, it was expected that they would not differ in recognition sensitivity across the normal and reversed conditions.

Although there was a main effect for skill on recognition sensitivity, supporting the findings presented in Experiment 1 and elsewhere (e.g., North et al., 2009; Williams et al., 2006), there were no significant effects for display or the Skill × Display interaction, with very low effect sizes being reported for the latter comparisons. The skill advantage was demonstrated in the absence of any difference in response bias between skilled and less skilled participants. The descriptive statistics reveal that the $d'$ values for the skilled participants were lower than those observed in Experiment 1, which suggests that even skilled participants found the task of distinguishing old from new stimuli in normal and reversed conditions difficult. Nevertheless, the values do indicate that skilled participants were able to successfully make these recognition judgements and could do so with significantly greater sensitivity than their less skilled counterparts across both normal and reversed conditions. These findings suggest that perturbing access to absolute motion does not negatively impact upon sensitivity when making recognition judgements.

When considered in conjunction with Experiment 1, findings suggest that skilled participants rely primarily on the relative motions between features when attempting to recognise previously viewed sequences. A caveat is that certain superficial display features were mirror invariant and thus unchanged by the reversal process (e.g., the stadium). It is therefore possible that skilled participants were using these features as well as the relative motions between display features. However, given findings from Williams et al. (2006) and North et al. (2009, 2011), where skill main effects were reported even when stimuli were presented as PLDs where all superficial information was removed, it appears more plausible that skilled players were using relative motion rather than specific display features for recognition. As with Experiment 1, it is important to note that less skilled participants recorded very low scores, and, consequently, it is difficult to draw conclusions about the nature of the processing undertaken by these participants when making recognition judgements.

## Experiment 3

In Experiments 1 and 2, data was presented to suggest that when attempting to make recognition judgements, skilled participants perceive crucial information based upon relative motions between features. However, less is known about which features are particularly important when making these judgements. In a series of experiments, Williams and colleagues (e.g., Williams et al., 2006; Williams & North, 2009; North et al., 2009, 2011) used a number of different experimental techniques to try and address this issue. In one experiment, a digital editing technique was used to occlude the positions of the two central offensive features (i.e., the most advanced offensive players) and their corresponding defensive markers with the background information on structured sequences of play, whereas a control condition involved the removal of peripheral players (see Williams et al., 2006, Experiment 3). The occlusion of the central offensive features removed or distorted access to important relational information and had a detrimental effect on performance when compared to the control condition, implying that the central offensive features are important when attempting to detect familiarity.

In two further studies, North et al. (2009, 2011) examined the issue of which features are used to support recognition decisions using complementary methodologies. In one study, eye movement data were recorded as skilled and less skilled participants made familiarity-based recognition judgements to structured sequences, whereas in the latter study, think-aloud retrospective verbal reports were gathered immediately after each trial. The skilled participants recorded a higher number of fixations on the central offensive features and made more fixation transitions from the ball to an offensive feature and vice versa than did less skilled participants. In a similar vein, skilled participants made significantly more verbalisations involving the movements of offensive features “off the ball” than less skilled participants, with the central offensive features being particularly important for the skilled participants. These data suggest that the ability to pick up relative motion information between a few key features is crucial.

In this final experiment, in an effort to better identify the key features, or combination of features, that are important when making familiarity-based judgements, different features and varying combinations of features were manipulated to evaluate their impact on subsequent recognition sensitivity using structured sequences of play only. In the control condition (Condition 1), four players were occluded from peripheral positions (e.g., the offensive fullbacks or centre backs as well as their corresponding defensive counterparts or the two opposing goalkeepers). In another condition (Condition 2), the two central offensive players and their corresponding defensive markers were occluded, while in another condition (Condition 3) two central midfield players as well as their defensive markers were occluded. In a final condition (Condition 4), one central offensive player and one central midfield player were occluded as well as their corresponding markers. It was hypothesised that skilled participants would show a reduction in response sensitivity on all three experimental conditions compared to the control condition; albeit given the partly exploratory nature of this experiment it was not possible to predict the exact nature of any differences that may exist across the three experimental conditions. In contrast, the less skilled participants were expected not to differ in recognition sensitivity across the four conditions owing to their proposed reliance on superficial display features when making these judgements.

## Method

### Participants

A total of 10 skilled and 10 less skilled male soccer players participated. The skilled participants (*M* age = 20.20 years, *SD* = 2.70) had previously played at a professional club's Academy and/or were currently playing at semi-professional level, and all played in defensive positions. These individuals had been playing soccer competitively for an average of 13.50 years (*SD* = 2.40). In contrast, the less skilled participants (*M* age = 19.50 years, *SD* = 2.50) had played soccer competitively for an average of 10.30 years (*SD* = 2.90), albeit only at a recreational or amateur level. None of the participants had taken part in Experiment 1 or Experiment 2.

### Test Stimuli

Participants were presented with separate films of test stimuli involving a viewing phase and recognition phase, respectively. The action sequences were taken from a sample of two matches from Football Association Youth Cup matches, neither of which included players who participated in this experiment. These matches were filmed from the same viewing perspective and employing the same equipment as that in Experiment 1. The film sequences were made up of structured trials only. The same procedures as those outlined in Experiment 1 were used to select suitable clips for inclusion in this experiment.

The viewing phase included 60 film clips, with an inter-trial interval of 5-seconds. The recognition phase contained 40 clips taken from the viewing phase, 10 from each viewing condition, and 20 new action sequences that had not been seen previously by the participants. The 40 clips that had previously been presented were manipulated using digital editing technology. The additional 20 clips that had not previously been presented were manipulated in the same way. In all, there were four edited conditions that acted to remove differing pieces of perceptual information from the film sequence for the entire duration of each clip. A panel of three expert coaches were consulted prior to the selection of occlusion conditions, and only those conditions and clips in which there was complete agreement were included. The four conditions were as follows:

- *Condition 1*: a control condition where four peripheral players who did not play in central offensive or midfield roles (i.e., full backs, goalkeepers) were occluded.
- *Condition 2*: where two central offensive players and their corresponding defensive markers were occluded.
- *Condition 3*: where two central midfield players and their corresponding defensive markers were occluded.
- *Condition 4*: where one central midfield player and one central offensive player were occluded, as well as their corresponding markers.

In total, there were 15 trials for each occluded condition in the recognition phase of the experiment. Of these 15 trials, 10 had previously been presented in the viewing phase, whereas 5 had not been presented earlier in the viewing phase. The order of presentation of video clips was randomly determined and was kept consistent across participants.

The procedure of occluding players was achieved by means of specialist editing software (Motion Key Analysis, Imagineer Systems Limited, New York, USA) that enabled the foreground (i.e., a player) to be replaced with the background (i.e., the playing surface/turf). Thus, display features were literally erased from each frame of action. Since attacking features are habitually marked by a defender, accompanying defensive markers were occluded for the duration of each trial.

### Apparatus and Procedure

The apparatus used to present the film clips and the experimental procedure were the same as those in Experiment 1. However, participants were informed that their task was to decide whether action sequences presented during the recognition phase were edited versions of video clips observed during the viewing phase, or completely novel clips that were not presented in the viewing phase. A brief familiarisation procedure was employed, during which participants viewed five examples of clips under normal and occluded viewing conditions, respectively.

#### Data Analysis

The dependent measures and analysis procedures were the same as those in Experiment 1, except that the within-participant factor had four levels (Conditions 1, 2, 3, and 4).

## Results

The analysis of *d*' revealed a significant Skill x Display interaction, $F_{3, 54} = 5.55$, $p < .01$, $_{p}^{2} = .24$. Skilled participants (*M* = 1.44, *SD* = .64) were significantly more sensitive when making recognition judgments in Condition 1 than their less skilled (*M* = - .01, *SD* = .32) counterparts, *d* = 2.87. In contrast, there were no significant differences in recognition sensitivity between skilled (*M* = .35, *SD* = .69) and less skilled (*M* = .19, *SD* = .53) participants in Condition 2, *d* = .26, or between skilled (*M* = .26, *SD* = .79) and less skilled (*M* = .07, *SD* = .39) players in Condition 3, *d* = .30. In Condition 4, skilled participants (*M* = 1.15, *SD* = .46) showed superior recognition sensitivity when compared with less skilled participants (*M* = .59, *SD* = .82), *d* = .84. The Skill x Display interaction is illustrated in Figure 2.4. There was a significant main effect for skill, $F_{1, 18} = 10.15$, $p < .01$, $_{p}^{2} = .36$. Skilled participants (*M* = .80, *SD* = .81) were more sensitive in making recognition judgments than their less skilled (*M* = .21, *SD* = .58) counterparts, *d* = .84. Finally, there was a significant main effect for display, $F_{3, 54} = 8.94$, $p < .001$, $_{p}^{2} = .33$. The Bonferroni corrected pair wise comparisons showed that participants were significantly more sensitive at making recognition judgments in Conditions 1 and 4, when compared with Conditions 2 and 3, *p*'s < .05, *d* = .58 and .71 respectively. There was no difference in recognition sensitivity between Conditions 1 and 4, *d* = .20, or between Conditions 2 and 3, *d* = .17, *p*'s > .05.

The analysis of *c* showed a main effect for display type, $F_{3, 54} = 12.02$, $p < .01$, $_{p}^{2} = .4$. Bonferroni corrected pair wise comparisons revealed participants showed a significantly lower criterion threshold, and hence a bias toward responding 'yes', in Condition 1 (*M* = -.23, *SD* = .28) than Condition 4 (*M* = .17, *SD* = .40), *p* < .05, *d* = 1.16. Participants also demonstrated a lower criterion threshold for Condition 3 (*M* = -.24, *SD* = .48) than Condition 2 (*M* = .35, *SD* = .43), *p* < .05, *d* = 1.29. There was no difference in criterion threshold between Conditions 1 and 3, and between Conditions 2 and 4, *p*'s > .05, *d*'s = .03 and .43 respectively. There was no main effect for skill, $F_{1, 18}$ = 2.47, $p$ >.05, $_{p}^{2}$ = .12, and no Skill x Display interaction, $F_{3, 54}$ = .11, $p$ >.05, $_{p}^{2}$ = .01.

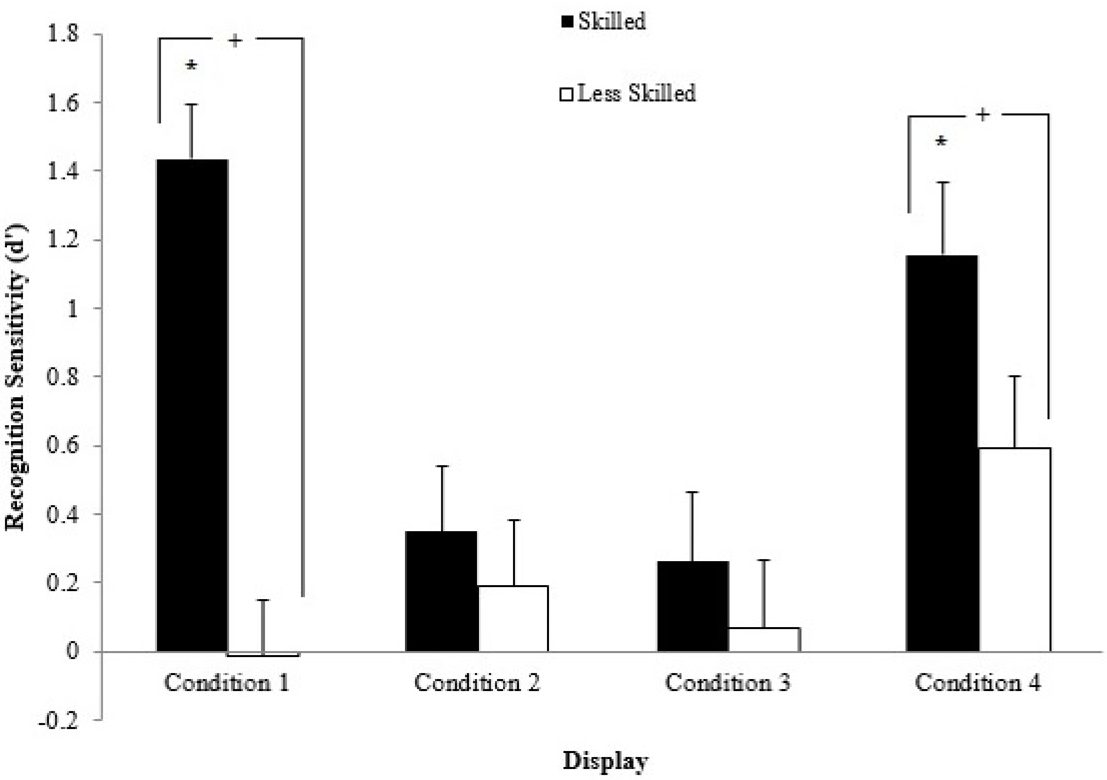


Figure 2.4: The Skill x Display interaction (with *SD* bars) for recognition sensitivity in Experiment 3. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

## Discussion

In this experiment, an attempt was made to identify the specific relative motion information that skilled participants extract from displays when making familiarity-based judgements. It was predicted, based on previous work (e.g., Williams et al., 2006), that skilled participants would show a significant decrement in performance when specific central features were occluded or erased from the film sequences during the recognition phase. However, it was not possible to make specific predictions as to the relative decrement in performance expected across the three experimental conditions. In contrast, it was hypothesised that the less skilled participants would not differ in their recognition sensitivity across the different occlusion conditions owing to their reliance on superficial display features that remain consistent across conditions.

The skilled participants showed a significant decrement in recognition sensitivity in Conditions 2 and 3, when compared to the control condition (i.e., Condition 1, $d$ = 1.64 and 1.64, respectively). The descriptive statistics reveal that the skilled performers found it very difficult to make successful recognition judgements in these conditions. It appears that either the two central offensive players or the two central midfield players, and their corresponding markers, provide important relative motion information that facilitates the recognition of familiar and unfamiliar playing sequences. When these sources of information are removed, skilled participants appear unable to perceive meaningful information and thus potentially revert to guessing. Skilled participants showed no significant difference in recognition sensitivity for Condition 4 when compared to the control condition, and they demonstrated better recognition sensitivity in this condition than their less skilled counterparts ($d$ = 0.83). A slightly unusual observation is that less skilled participants seemed better able to make recognition decisions in Condition 4 than in the other three conditions, where they appeared unable to do so. Findings suggest that the relative motion information between features in complementary, yet different, positional roles (i.e., forwards and midfield players) may be more important than the relative motions between features with shared positional responsibilities (i.e., pairs of offensive features or midfield features). In the case of less skilled participants it may be that removal of two features in different positional roles simplified the display and allowed them to access the important structural information with greater ease. Clearly, these latter propositions require confirmation in subsequent work.

## General Discussion and Conclusions

In this chapter, a series of experiments were presented to investigate how skilled participants process stimuli and identify the information that is used when making recognition judgements in a time-constrained, dynamic environment involving interactions between numerous display features. In previous work, it has been established that skilled participants are more likely to use relational information either through the positions of display features or the motions that arise between them to make recognition judgements (see North et al., 2009, 2011; Williams et al., 2006). An attempt was therefore made to extend knowledge of this issue by manipulating access to positional and motion information in their various guises in three separate experiments. Experiment 1 examined whether participants rely on positional or motion information when making such judgements. Experiment 2 examined the relative importance of absolute and relative motion information. In Experiment 3, an attempt was made to identify the specific relative motions that participants use when making recognition judgements.

The data provides a clearer and more complete understanding of how skilled performers make such judgements. In Experiment 1, skilled participants showed a significant decrement in recognition sensitivity when motion information was removed from the display, leaving behind only superficial display features and relational information from the positions of players. A significant decrement in recognition sensitivity was apparent for skilled participants when the same amount of information was presented as that contained in dynamic sequences, but motion information was removed by presenting the individual frames in a randomised order. In contrast, no differences were apparent in recognition sensitivity for the less skilled participants across these conditions, although the descriptive statistics suggested that they were unable to successfully complete the task and most likely reverted to guessing rather than extracting any specific type of information to inform their recognition decisions. So, the extraction of motion information appears a key mechanism underpinning successful recognition in skilled participants. In Experiment 2, an attempt was made to identify the specific motion information that may be of relevance. No decrements in performance were observed when distorted absolute motion was distorted (by mirror-reversing stimuli) from individual display features (players and ball). Since it was assumed that common motion would remain constant across all conditions, the only common movement between the players and the ball being up or down the pitch, it was concluded that skilled participants pick up the key relative motions between display features when making these types of judgement. Although skilled participants outperformed their less skilled counterparts in both conditions, given the apparent inability of less skilled participants to complete the task and their seeming reliance on guessing, it is not possible to draw conclusions on the type of information used by less skilled participants to make these decisions. In Experiment 3, the data showed that the relative motions between only a few key features are crucial, notably the relationships between the central offensive and central midfield players, whereas motions between pairs of offensive or midfield players as well as other more peripheral features are less important. In summary, the results provide evidence that skilled participants recognise dynamic displays showing interaction between multiple elements by perceiving motion and, specifically, relative motion within the display. Specifically, findings suggest that maintaining the relative motions between features in two different central locations (midfield and offence) are critical for skilled participants to perceive meaning and structure to inform their recognition decisions.

The reported data provides support for the Interactive Encoding Model proposed by Dittrich (1999; Dittrich & Lea, 1994). This model suggests that when recognising familiarity in dynamic sequences, skilled observers rely upon the relational information between features, more specifically, based on this programme of work, the relative motions between only a few key features and the associated higher order strategic information conveyed by these relations. The use of relative motion information between a few key features (i.e., players) satisfies the initial low-level stage of processing outlined in the Interactive Encoding Model. In this two-stage model, skilled participants initially extract low-level relational information between features. This low-level information is then matched against a high-level internal template/cognitive representation that skilled individuals have developed as a consequence of their extended experience within the domain (e.g., Ford, Ward, Hodges, & Williams, 2009; Ward et al., 2007). A related proposal is that skilled participants develop complex retrieval structures in long-term memory as a function of experience (Ericsson & Kintsch, 1995). Once activated, the appropriate retrieval structure is employed to interpret and evaluate future situations and decide upon an appropriate response. It is speculated that the relative motions between display features act as a cue to stimulate these complex retrieval structures in long-term memory. The skilled performer can judge the observed display in relation to previously encountered stimuli represented in the retrieval structure and make an appropriate decision.

One observation across experiments was that while skilled participants consistently outperformed their less skilled counterparts in their ability to distinguish between familiar and novel sequences, the less skilled participants were apparently unable to successfully complete the task. It is therefore not possible to draw conclusions about the type of information used by less skilled participants to make familiarity-based recognition decisions, and no additional support is presented for the earlier prediction that less skilled participants would use superficial surface-level features to make these decisions (e.g., see Williams et al., 2006). Previously, it has been reported that less skilled performers are able to successfully make recognition judgements (albeit significantly less accurately than skilled participants) to provide evidence for the type of information processed by this population (e.g., Williams et al., 2006). One explanation may be that given the subtle manipulations between conditions employed in this research, the less skilled participants were unable to perceive differences between new and old stimuli, and thus in the case of less skilled participants the recognition paradigm was not a sufficiently sensitive task. In their meta-analysis of research into perceptual–cognitive expertise, Mann and colleagues (2007) concluded that methodologies requiring the same encoding, retrieval, and application of information such as predictive anticipation tasks and field-based methods were significantly more sensitive than recognition and recall-based measures, which is supported by the observed findings and the *d’* values reported in this chapter.

It should be acknowledged that the specific importance of surface features and relational information in its various guises may differ as a function of scene properties (Goldstone, Medin, & Gentner, 1991) and the type of cognitive activity that may be engaged in the task (Holyoak & Koh, 1987). Consequently, it may be difficult to generalise existing findings across very different contexts or domains, albeit common underlying mechanisms are likely to be evident irrespective of the specific context or domain. An interesting issue is whether or not the ability to successfully recognise familiarity in the display may be improved through, for example, traditional concepts of imprinting (Goldstone, 1998). Several authors have argued that the ability to identify familiarity is an important component of anticipation skill. Consequently, and with a better understanding of the information that participants extract from the display when making such judgements, it should increase opportunity to develop systematic training programmes to try and improve this skill across domains (e.g., see Smeeton, Williams, Hodges, & Ward, 2005; Williams, Ward, Knowles, & Smeeton, 2002).

# Chapter 3: Identifying the Minimal Essential Information Underpinning Familiarity Detection in Dynamic Displays Containing Multiple Objects

## Abstract

This chapter examined the minimal essential information required to successfully recognise patterns in dynamic, interactive stimuli. An exploratory spatial occlusion approach was employed which acted to remove most of the perceptual information available to the performer to determine whether structure could be perceived from the limited information remaining. In an initial viewing phase, skilled and less-skilled soccer players were presented with structured PLD action sequences showing dynamic footage occluded at the final frame prior to an attacking pass being made. During the subsequent recognition phase, participants were presented with new and previously seen stimuli and were required to make judgments as to whether or not each sequence had been presented earlier. Action sequences were selectively edited to occlude a number of features and create three experimental conditions; Condition 1 showed only two peripheral players, Condition 2 presented the two central offensive players, and Condition 3 showed two central offensive players as well as the player in possession of the ball. Findings demonstrated how there was no difference in recognition accuracy between skilled and less-skilled participants when just peripheral players were presented. In contrast, when presented with the relative motions of the two central offensive players, skilled participants were significantly more accurate at detecting familiarity than their less skilled counterparts. This skill advantage was increased further when a ball (target feature) was included against which these relative motions could be judged against. The Skill x Display interaction provided evidence to suggest that skilled players perceive and recognise global patterns on the basis of localised information sources. Specifically, the relative motions between central offensive players represents the minimal essential information required to recognise patterns in dynamic soccer action sequences.

**Keywords:** *Expertise; Pattern-Recognition; Spatial Occlusion; Point-Light-Display; Relative Motion*

As outlined in Chapter 2, the ability to recognise visual stimuli to perceive the intention of others is imperative to the successful completion of everyday tasks, such as driving a car (McKenna & Horswill, 1999), or simply crossing the road (Carsten, Tight, Southwell, & Plows, 1989). The capacity to selectively attend to only the most relevant environmental cues while disregarding extraneous information becomes particularly important under temporal constraints, and is therefore a significant precursor to expert performance in a variety of domains. A potentially crucial skill is the ability to identify structure, or meaningful patterns across display features, which has been illustrated when attempting to detect threatening pieces in board games such as chess (e.g., Charness et al., 2001), undertaking diagnostic imaging tasks (Nadine & Kundle, 1987), and perceiving patterns of play in soccer (e.g., Williams et al., 2006).

An understanding for domain-specific patterns is considered to be an important perceptual process and defining characteristic of experts in fields where individuals are required to make decisions and anticipate future events (Abernethy, Baker, & Cote, 2005; Smeeton, Ward, & Williams, 2004). The seminal work of De Groot (1946/1965) demonstrated how grandmaster level chess players were able to recall positions of chess pieces with near perfect accuracy after only brief exposure, whereas lesser skilled players were unable to do so. Elaborating on De Groot's research, Simon and Chase (1973) found that the expert advantage was lost when players were asked to recall random configuration of chess pieces. The pioneering work of Allard and colleagues (1980) was the first to introduce methodological paradigms traditionally used in cognitive psychology to that of a sporting context, effectively differentiating between expert and novice basketball players on structured trials only. Similar observations have since been extended to various other sports, including American football (e.g., Garland & Barry, 1991), field hockey (Smeeton, Ward, & Williams, 2004) and soccer (e.g., Williams et al., 1993), as well as self-positions in a performance routine in gymnastics (Imwold & Hoffman, 1983) and figure skating (Deakin & Allard, 1991).

It is widely believed that skilled individuals develop domain-specific knowledge structures as a result of prolonged engagement within their chosen discipline, which accounts for their expertise (Ericsson, Nandagopal, & Roring, 2009). Researchers have postulated over the underlying mechanisms of expert performance for many years, giving way to various skill-based theories of memory derived from the cognitive psychology literature. These domain specific knowledge structures have been referred to as "chunks" (Chase & Simon, 1973), "templates" (Gobet & Simon, 1996b), and "retrieval structures" (Ericsson & Kintsch, 1995), and are considered to be comprised of several individual items which are connected or related to each other. It is proposed that these cognitive knowledge structures direct attention to task-specific stimuli, allowing experts to reduce the complexity of a display, enabling information to be encoded more quickly, and thus facilitating pattern-recognition. In contrast, and with fewer practice hours, novice performers are not able to develop such elaborate cognitive structures to guide their attentional and perceptual processes, meaning they can be easily overwhelmed by the complexity of a display, resulting in an impairment of their ability to recognise patterns (Bilalic, Langner, Erb, & Grodd, 2010).

Regardless of whether the performer is an expert chess player or an elite soccer player, they are faced with displays that comprise of multiple objects, events, and an almost infinite number of functional relations, all of which compete for visual attention (Chun, 2000). It is argued that these performers are able to use attentional mechanisms, directed by cognitive knowledge structures, to prioritise and select only information that is relevant, meaning only a small part of the visual scene is selected and encoded to build more elaborate memory traces (Chun, 2000; Didierjean & Marmeche, 2005; Hollingworth & Henderson, 2000). Recent research on face recognition by Royer, Blais, Gosselin, Duncan and Fiset (2015) supports these assertions and challenges the popular view that faces are perceived, encoded and recognised as 'wholes' (see DeGutis, Wilmer, Mercado, & Cohan, 2013; Richler & Gauthier, 2014). Using a ‘bubbles technique’, Royer et al. (2015) were able to restrict the amount of visual information presented to participants and demonstrated that the more expert someone was at recognising faces the fewer facial features they needed to see in order to make successful recognition judgements. Similarly, by recording eye movements, Bilalic et al. (2010) were able to show that expert chess players only fixated on a select few chess pieces, whereas novices fixated on almost every single individual feature. It appears that experts’ knowledge guides their perceptual processes and means they selectively attend to and encode only the most critical information.

The demands and challenges a performers faces are magnified when they must recognise patterns in dynamic and time constrained tasks (e.g., military aviation, crowd control, and sports such as soccer and ice-hockey) as the information is always different from one moment to the next and the processes which underpin pattern-recognition may be different to those in static, self-paced tasks (e.g., chess). Dittrich’s (1999) interactive encoding hypothesis provides an explanation for how humans recognise continually evolving stimuli involving dynamic interactions between multiple features. Motion information of, and between, display features are initially proposed to be encoded using ‘bottom-up’ low level processes before this information is then matched to an internally stored semantic template using higher order ‘top-down’ processes. A similar proposal has also been made by Wong and Rogers (2007) in their recognition of temporal patterns theory in which they argue for a pre-processing stage, during which only the necessary information for pattern classification is extracted before this information is subsequently matched to a known template in memory. Support for this initial phase comes from research which demonstrates that humans are incredibly adept at perceiving biological motion when presented with point light displays (see Jastorff, Kourtzi, & Giese, 2006; Mather & Murdoch, 1994; Shim, Carlton, & Kim, 2004), whilst the observation of an expert advantage in perceiving biological motion (see Ward et al., 2002) implies a role for higher order 'top-down' processes.

While there remains a vibrant debate as to the exact theoretical mechanisms underpinning expertise in sport (Ward & Williams 2007), researchers have only recently begun to try and identify the specific nature of information extracted from the visual display when making familiarity judgments. In a series of experiments reviewed in Chapter 2, Williams et al. (2006) provided evidence that skilled soccer players process dynamic displays as a function of relational information between features in order to inform pattern-recognition. Although this concurs with extant literature in the field (e.g. Gauthier & Tarr, 2002; Maurer, Le Grand, & Mondloch, 2002; North et al., 2009, 2011), as well as Dittrich's interactive encoding model (1999) and the pre-processing stage of Wong and Roger's (2007), it is not known whether experts perceive and encode the positional information of display features an isolated point in time, or via the motion information between these features. The previous chapter examined this issue in greater detail by presenting skilled and less-skilled participants with dynamic film displays showing multiple independent, yet interacting, features before making recognition judgments to three different types of stimuli; dynamic, static, and random. Dynamic stimuli contained relational and motion information; static stimuli showed only the final frame of a sequence for the same duration of time as dynamic clips which maintained relational but removed motion information; while the random stimuli presented each individual frame from a dynamic sequence in a random order so that the same amount of information was presented but relational and motion information were disrupted. Findings showed how skilled participants demonstrated a recognition advantage for dynamic stimuli only, inferring that the low level information extracted before matching to a semantic template is encoded on the basis of motion information.

The dynamic stimuli employed in the previous chapter contained both absolute and relative motion, it was therefore not possible to determine whether the initial 'bottom-up' perceptual processes were based on extracting relative motions between players or the absolute motion of one or more feature(s) (Hill & Pollick, 2000). To this end, Dittrich and Lea (1994) originally argued that either motion information of isolated independent features (i.e., absolute motion) or interactions between various independent features (i.e., relative motion) could be encoded. A second experiment was therefore conducted whereby skilled and less skilled participants completed recognition tasks, presenting both normal dynamic stimuli and mirror reversed dynamic stimuli to examine whether distorting access to absolute motion information affected familiarity judgments across skill groups. The process of reversing the sequences ensured the relative motions between features all remained the same (as well as the superficial surface features), while the directional movement of individual features such as the ball (i.e. absolute motion) was reversed. In line with extant literature, skilled participants demonstrated superior recognition sensitivity over their less skilled counterparts, yet no significant differences were observed across viewing conditions, suggesting that skilled participants encode relative motion between features, rather than absolute motion when attempting to recognise familiarity in dynamic, interactive stimuli.

Although recent research has identified the broad processing mechanisms that underpin pattern-recognition, Wong and Rogers (2007) highlighted that the fundamental challenge is for researchers to identify the minimal set of features which enable accurate pattern-recognition. Using a spatial occlusion technique, the final experiment in the previous chapter attempted to identify the key features, or combination of features that are important during skilled pattern-recognition in soccer. Skilled and less skilled participants were presented with a recognition task displaying dynamic stimuli during which localised relative motions between certain display features were disrupted, whereas superficial surface features, and to a lesser extent the locations of players remained consistent. In line with earlier research (e.g., Williams et al., 2006; Williams & North, 2009; North et al., 2009; 2011), findings revealed a significant decrement in recognition performance for the skilled players when centrally located offensive features were occluded compared to those situated in more peripheral positions.

In order to substantiate these findings and extend the current body of literature in this field, the current study aims to identify the minimal essential information that is required to perceive and recognise temporal patterns in the domain of soccer. Within any display, and in addition to the 'global pattern' (i.e., the interactions between all display features), there are a series of localised 'micro patterns' (i.e., interactions between smaller numbers of insular display features). In line with recent research pertaining to face recognition (see Royer et al., 2015), the main aim was to determine whether participants were able to recognise global patterns on the basis of micro patterns between a limited number of display features. Similarly, are certain localised patterns more important that others, and can these provide the minimal essential information to inform successful pattern-recognition judgments?

Given the complexity of erasing a large number of players using a spatial occlusion procedure (as evidenced in Experiment 3 of Chapter 2), the test film in the current study was converted to point-light display (PLD). Using this technique, the location and movements of players are presented as points of light against a black background along with the position of the ball, whilst pitch markings are made up of a series of white lines. As a result, access to superficial display features such as environmental conditions and form cues emanating from players' postural orientation are eliminated, leaving only the positional and relational information between features, as well as the possibility of extracting higher-order strategic information from these relations (cf., Gentner & Markman, 1997). Despite such manipulations, researchers have demonstrated that when presented with dynamic images in PLD, participants are able to perceive the type of emotion expressed in a dance routine (e.g., Brownlow, Dixon, Egbert, & Radcliffe, 1997), and the mass of an object lifted by an individual (Shim, Carlton, & Kim, 2004). More importantly to the present chapter, this presentation method has elicited skill-based differences in previous soccer-specific research using the recognition paradigm (e.g., North & Williams, 2009; Williams et al., 2006).

With regards to the general design of the study, participants were initially presented with a series of dynamic PLD stimuli showing multiple individual objects that represented players interacting in a structured invasion game. In an almost inverted approach to Experiment 3 in the preceding chapter, stimuli in the recognition phase were edited to produce three occlusion conditions, each showing different micro patterns. Condition 1 showed only the positions and movements of two peripheral display features with all other information being occluded. Condition 2 presented the positions and movements of only the two central attacking players, whereas in Condition 3 the positions and movements of the two central attacking players along with the player in possession of the ball was presented.

In line with findings from visual search (North et al., 2009) and the spatial occlusion methods employed in the previous chapter indicating the importance of central offensive features, it was hypothesised that skilled participants would demonstrate superior recognition performance in Conditions 2 and 3 when compared to Condition 1, given the relative motions between the central offensive features in these action sequences is maintained. In terms of any potential differences between Conditions 2 and 3, it could be argued that with access to more perceptual information from the player in possession of the ball, participants would logically demonstrate superior performance for Condition 3. Evidence has however been provided to suggest that an important perceptual process in skilled recognition is the ability to quickly locate a central organising feature around which other features are likely to be encoded relative to. For example, in the previously discussed work of North et al. (2009), eye-movement data revealed how skilled players attempted to locate the position of the ball as early as possible in the action sequences since most information is likely to be relative to its position on the field. In a similar vein, Charness and colleagues (2001) demonstrated how in check detection situations in chess, the ‘King’ becomes a central organising feature with experts then making ‘visual pivots’ between other salient pieces to facilitate accurate pattern perception and inform their next move. Taken together these research findings provide a rationale for expected differences between Conditions 2 and 3 in the current study, where it was predicted that the skilled players would demonstrate greater recognition accuracy for Condition 3 given the presence of the player in possession of the ball.

With regards to less skilled players, it was predicted that they will perform at a level no greater than chance in Conditions 1 and 2, with research providing evidence to suggest they rely on more superficial display features rather than relational information when attempting to detect familiarity within dynamic action sequences (Gentner & Markman, 1997; Williams et al., 2006). Thus, given the clips are presented in PLD format, this was expected to inhibit their recognition performance considerably. Conversely, and in a similar vein to the skilled players, it was envisaged that they would perform marginally better in Condition 3 where the movement of the ball was maintained for the duration of each clip. To this end, not only did they have access to slightly more perceptual information, but research has shown their tendency to ‘ball watch’ when making familiarity judgments to interactive soccer stimuli, especially when presented in PLD format (North et al. 2009, 2011).

## Method

### Participants

A total of 10 skilled and 13 less skilled male players participated. Skilled participants (*M* age = 21.8 years, *SD* = 2.2) had previously played at a professional club's Academy and/or were currently playing at a semi-professional level and all played in defensive positions. Participants had been playing soccer competitively for an average of 12.9 years (*SD* = 3.1). In contrast, less skilled participants (*M* age = 20.9 years, *SD* = 2.6) only played soccer at a recreational or amateur level and had been participating for an average of 10.7 years (*SD* = 3.1). All participants reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of Liverpool John Moore's University. Participants provided informed consent and were free to withdraw at any stage.

### Test Stimuli

The test films included structured offensive sequences of play taken from the same battery of clips used in Chapter 2, such that the filming position and rating protocol for each sequence were the same as outlined in the methodology of Chapter 2. The action sequences were converted to PLD, with the attacking team presented as green points of light while their opponents were red, and the ball was white. These colours remained constant from one trial to the next and did not reflect the colour of the players' uniforms during the actual matches. An example of how a normal video action sequence can be transformed into PLD format is shown in Figure 3.1.

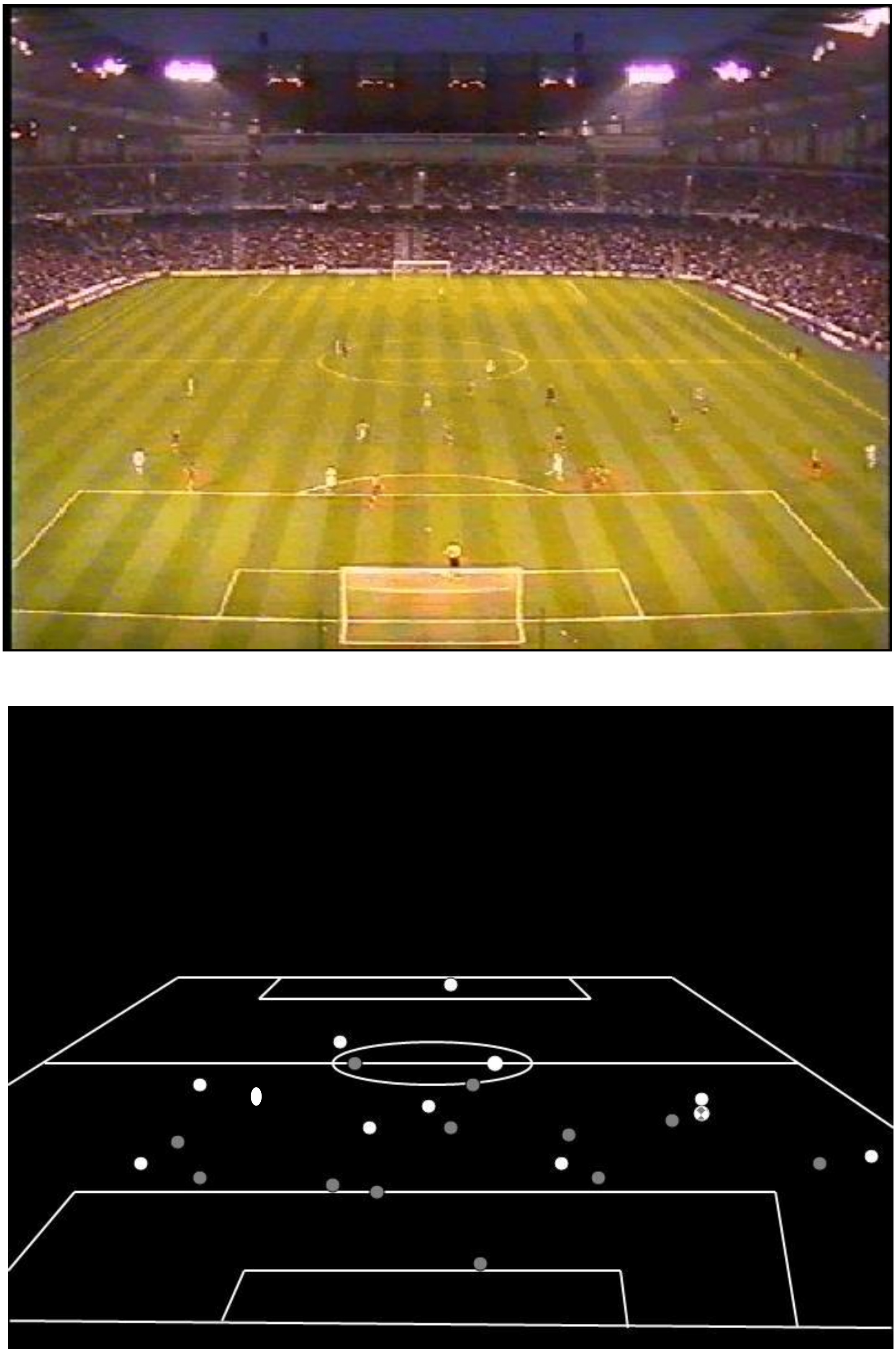

Figure 3.1: A frame from a typical structured trial presented in a) video and b) PLD.

Participants were presented with two separate test films; an initial viewing phase test film followed by a recognition phase test film. The viewing phase contained 18 action sequences, each of which was 5-secomnds in length and showed a developing attacking sequence that finished when the player (or point of light) in possession of the ball was about to make an attacking pass. There was a five-second inter-trial interval between the conclusion of one clip and onset of the next. The recognition phase also contained 18 action sequences, 12 of which had been presented previously, whilst 6 were novel. The 18 clips in this test film were randomly divided into x3 conditions which attempted to isolate relative motion information between specific features by occluding all other display features. Specifically, Condition 1 contained only two peripheral features that were far away from the focus of the action contained in the clip and were thus considered irrelevant to the passage of play. Typically, these were mainly defensive players for the attacking team in the opposite half of the pitch to the ball/action area (see Figure 3.2). Condition 2 showed only the 2 central attacking players for the offensive team, who occupied 'typical' striker positions in a 4-4-2 formation when their team was on the attack (see Figure 3.3). Using the same criteria as Condition 2, Condition 3 showed the central attacking players as well as the player in possession of the ball. Examples of still frames from each of these conditions are shown in Figures 3.2 to 3.4. The recognition phase contained six clips from each of these conditions. For each subset of six clips, four were edited versions of clips that had been presented in the viewing phase and two were edited versions of clips that had not been presented previously in the experiment. Action sequences in the recognition phase were presented in a randomised order that was kept consistent across participants. As in the viewing phase, all clips in the recognition phase were five-seconds in length with a five-second inter-trial interval between the conclusion of one clip and the onset of the next.

Figure 3.2: Example frame from Condition 1 where two peripheral players are presented.

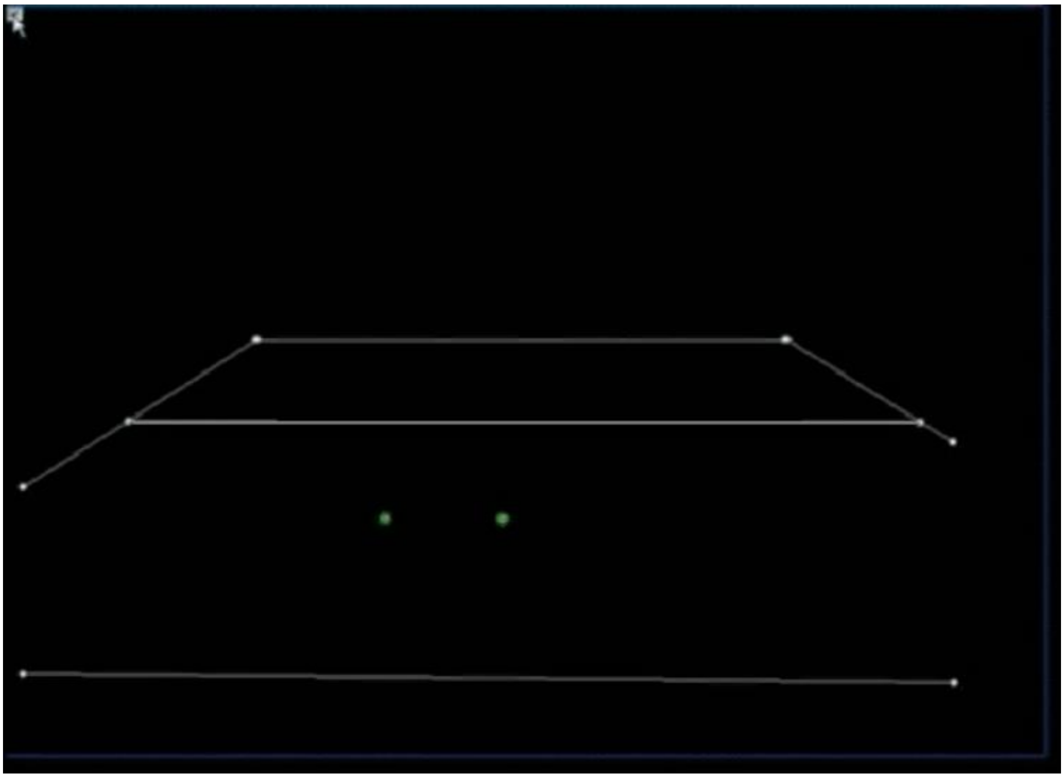

Figure 3.3: Example frame from Condition 2 where two central forward players are presented.

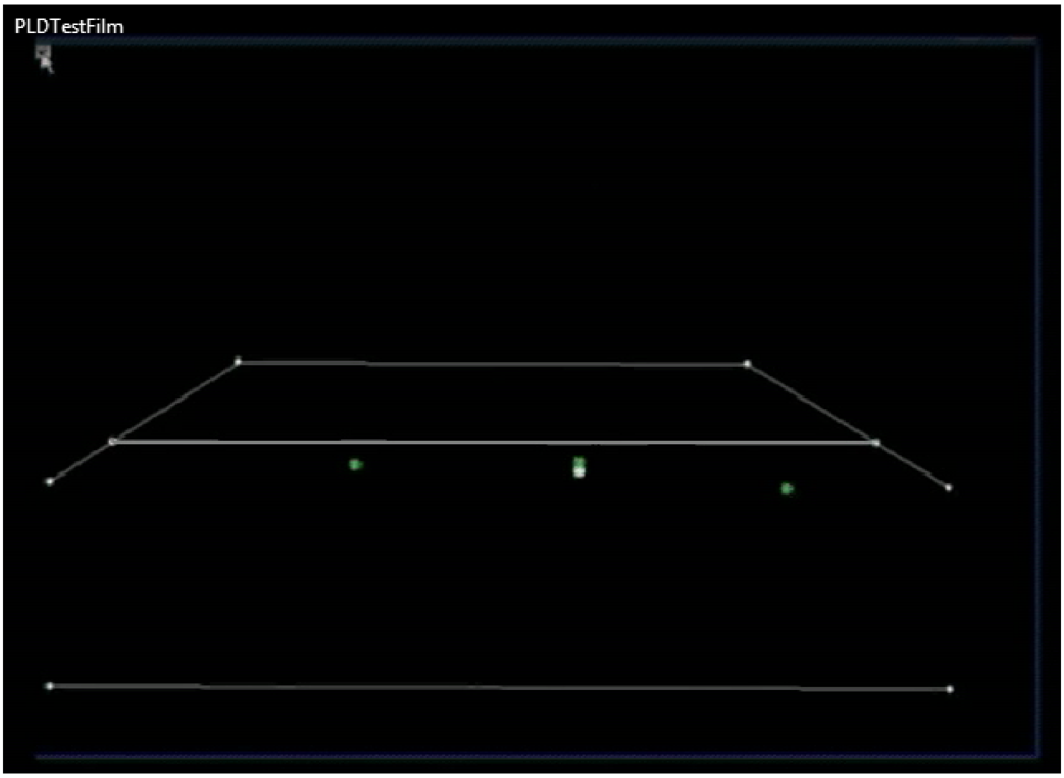


Figure 3.4: Example frame from Condition 3 where two central forward players and the player in possession of the ball are presented.

**Apparatus**

In order to convert the action sequences into PLD, the clips were saved into “avi” format using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA). They were then exported via IrfanView (www.irfanview.com) to the software package AnalysaSoccer (Liverpool John Moores University, UK) which allowed the players’ positions and movements from the original film to be digitised and reconstructed so that they were represented as points of light against a black background using real-time video playback. Due to the complexity and time consuming nature of the process, only the outside pitch markings as well as the halfway line were depicted, meaning the centre circle and penalty areas were omitted from the final edit of the clips. Once created the PLD clips were assembled into a test film to create the viewing and recognition phases respectively, which were presented using a

DVD player (Panasonic, DMR-E50, Osaka, Japan) and projector (Sharp, XG-NV2E, Manchester, UK) with images being presented onto a 9' x 12' screen (Cinefold, Spiceland, IN, USA) at a rate of 25 frames per second with XGA resolution.

**Procedure**

Participants were tested individually and sat in a chair 3-metres from the projection screen such that the image subtended a viewing angle of approximately 40-degrees. Prior to being shown the viewing phase film, participants were told they would be presented with a series of clips, all five-seconds in length, showing PLD sequences of play in soccer that would build up to a point where the player in possession (or point of light) was about to make an attacking pass, however each clip would occlude at the final moment before this event occurred. Participants were instructed to watch the clips as if playing in the match, adopting the perspective of a central defender, but were told that no specific response was required while viewing these clips.

. After presentation of the viewing film, there was a 10-minute break during which participants completed a practice history questionnaire relating to their soccer experience and skills. They were then informed they would be presented with another series of action sequences, all of which were again in PLD format, but that all of the clips in the recognition phase test film had been edited so as to only show certain points of light and that all others had been removed. The participants were told that some of these clips were edited versions of clips that had been presented in the earlier viewing phase, whereas others were edited versions of clips that had not been presented previously. Participants were instructed to watch each clip for its duration and their task then was to make a familiarity judgment as to whether the clip was an edited version of one that had been presented in the earlier viewing phase (i.e., respond "yes") or not (respond "no"). Participants made their responses using a pen and paper response sheet. Prior to completing the recognition phase, a familiarisation procedure was employed in which participants were presented with three examples from each of the edited conditions.

### Data Analysis

Recognition accuracy was calculated by dividing the total number of correct familiarity judgments by the total number of clips presented and then multiplying by 100 to give a percentage accuracy score. Recognition accuracy was then analysed using a mixed design 2-way analysis of variance (ANOVA) in which the between participants factor was skill (skilled vs. less skilled) and the within participants factor was display (peripheral players vs. central offensive players vs. central offensive players + player in possession). The data were tested for normality using a Shapiro-Wilks test, and this assumption was satisfied. Partial eta squared values ($\eta_p^2$) are provided as a measure of effect size for all main effects and interactions. Cohen's *d* measures are reported where two means are compared. For the repeated measures variables, violations of sphericity were corrected by adjusting the degree of freedom using the Greenhouse Geisser correction when the sphericity estimate was less than 0.75, and the Huynh-Feldt correction when greater than 0.75 (Girden, 1992). Any post-hoc tests of within-group differences were conducted using Bonferroni-corrected comparisons. The alpha level for statistical significance was set at $p < .05$.

## Results

ANOVA revealed a significant Skill x Display interaction; $F_{1.78,\ 37.29} = 5.672$, $p < .01$, $\eta_p^2 = 0.213$. Skilled participants were more accurate than less-skilled participants in their recognition judgments when presented with only the movements of central offensive players (Condition 2) ($M = 62.50$ %, $SD = 14.43$ vs. $M = 43.27$ %, SD = 9.70), and when presented with the movements of central offensive players plus the player in possession of the ball (Condition 2 + Condition 3) (*M* = 77.50 %, *SD* = 5.27 vs. *M* = 51.92 %, *SD* = 12.34), *d*'s = 1.56 and 2.70 respectively. In contrast, there was no significant difference between skill groups when presented with only two peripheral display features (Condition 1) (*M* = 45 %, *SD* = 10.54 vs. *M* = 39.42 %, *SD* = 10.01), *d* = 0.54. This interaction is illustrated in Figure 3.5.

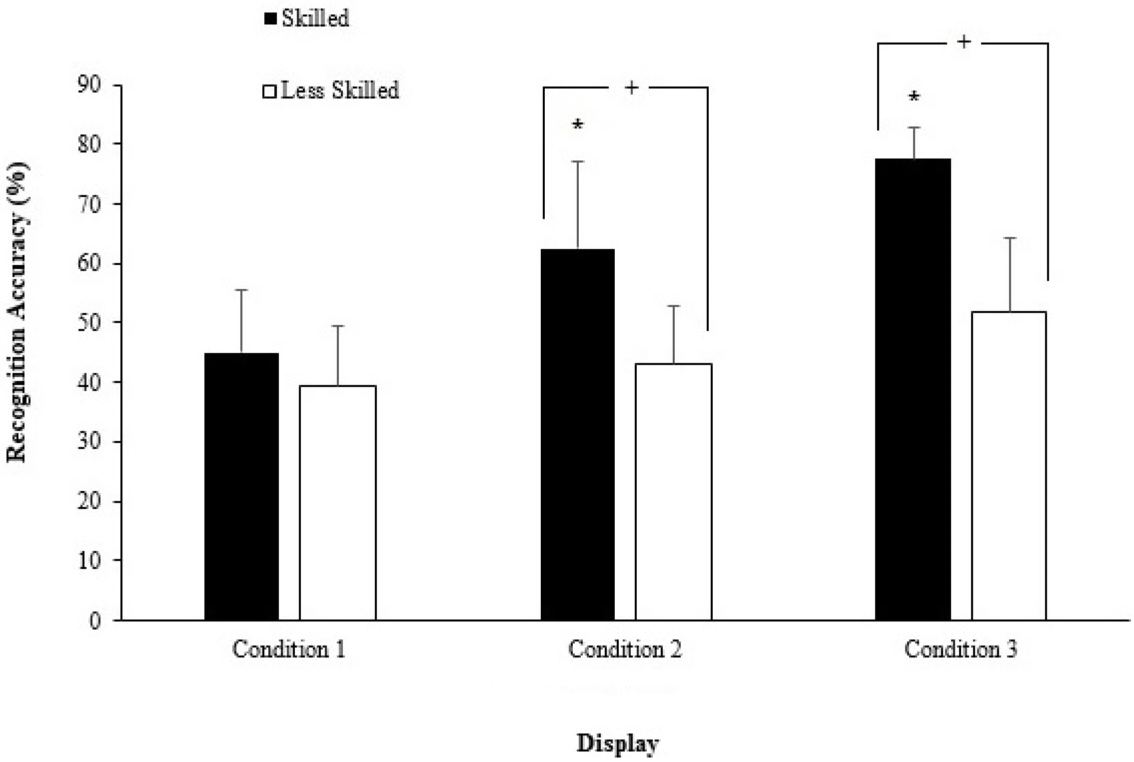


Figure 3.5: The Skill x Display interaction (with *SD* bars) for recognition accuracy. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

The main effect for skill was significant; $F_{1, 21} = 34.494$, $p < .01$, $\eta_p^2 = 0.622$. Skilled participants (*M* = 61.66 %, *SD* = 7.56) made more accurate recognition judgments than less-skilled participants (*M* = 44.86 %, *SD* = 6.17), *d* = 2.44. Finally, there was a main effect of display on recognition accuracy, $F_{1.78, 37.29} = 27.514$, $p < .01$, $\eta_p^2 = 0.567$. Bonferroni-corrected pairwise comparisons demonstrated that participants were significantly more accurate in their recognition judgments for Condition 3 when presented with two central offensive players plus the player in possession of the ball (*M* = 63.04 %, *SD* = 16.2) when compared to Condition 2 when only presented with two central offensive players (*M* = 51.63 %, *SD* = 15.22), or in Condition 1 when only presented with two peripheral players (*M* = 41.85 %, *SD* = 10.4), p's < .05, *d*'s = 0.73 and 1.56 respectively. Recognition performance was also significantly more accurate in Condition 2 when presented with just two central offensive players than in Condition 1 when presented with two peripheral players, *d* = 0.75.

## Discussion

The aim of this study was to identify the minimal essential information required to recognise patterns in dynamic displays containing multiple objects. Previously, researchers have presented evidence that skilled performers encode relationships between features (see North et al., 2009, 2011) as a function of relative motion information (see Williams et al., 2012) when detecting familiarity. Furthermore, recent findings in chess (Bilalic et al., 2010) and facial recognition (Royer et al., 2015) suggest that experts only need to attend to a select few display features in order to perform successfully. In view of these observations, the current chapter examined whether the relative motion information between localised display features in dynamic stimuli was sufficient to recognise a larger pattern and, if so, whether relationships between certain display features provided more important information than others. Skilled and less skilled soccer players were initially presented with a series of dynamic PLD sequences of play, and were later asked to complete a recognition task to stimuli that had been edited to show only the relations between a limited number of display features. As a brief overview, Condition 1 showed two peripheral players, Condition 2 presented the two central attacking players, and Condition 3 displayed two central attacking players as well as the player in possession of the ball.

In line with hypotheses, a Skill x Display interaction was observed, as skilled participants demonstrated superior recognition accuracy over their less-skilled counterparts when presented with two central attacking players ($d$ = 1.56), and these two features as well as the ball ($d$ = 2.70). In contrast, their recognition accuracy deteriorated to the level of less-skilled participants when presented with only two peripheral players ($d$ = 0.54). Although previous research has provided evidence to suggest that experts encode the relational information between display features (see Gauthier & Tarr, 2002; Maurer et al., 2002; Williams et al., 2006, 2012), findings from the current study infer that not all sources of relative motion in a display are equal. More specifically, certain micro-patterns within a display's overall configuration may be much more important (i.e., central offensive features), whereas others may be redundant in the encoding process (i.e., the two peripheral objects in the displays in this experiment).

Findings support those reported in both chess (see Bilalic et al., 2010) and face recognition (see Royer et al., 2015) which provided evidence to suggest that skilled performers only need to fixate on a select few stimuli within a display in order to make successful recognition judgments. In line with the LTWM theory (Ericsson & Kintsch, 1995), it is proposed that experts develop elaborate task-specific retrieval structures in the long-term memory, enabling attention to be directed to only the most important information sources within a visual display. In lieu of the current findings, it appears that the functional relations between the central offensive players and/or the player in possession of the ball were sufficient to stimulate these complex retrieval structures, as when these limited sources of information were presented in isolation, skilled performers were successfully able to judge the observed display (micro patterns) in relation to the previously encountered stimuli (macro pattern) to facilitate their pattern matching/recognition judgments. Conversely, and given their comparative lack of experience, it is proposed that less-skilled performers have fewer and/or less refined representations in their long-term memory, and were thus impaired in their ability to attribute meaning to the relational information in the presented stimuli, hence their inferior recognition performance.

The proposal that the relative motion information between the central offensive players provides the minimal essential information to recognise global patterns concurs with previous soccer-specific research that has employed complementary process tracing measures (North et al., 2009; 2011), and spatial occlusion techniques (Williams et al., 2006; 2012). Using visual search data, North et al. (2009) found that skilled participants recorded a higher number of fixations on central attacking players and made more fixation transitions from the ball to an attacking feature and vice versa, when compared with lesser skilled participants. In a subsequent study, North et al. (2011) found that skilled players also made significantly more verbalisations involving the movements of attacking players 'off the ball' than less skilled players, with the central offensive players being particularly important participants when sequences were presented in PLD. Similarly, Williams et al. (2006) found that recognition accuracy deteriorated for skilled participants when central offensive players were selectively occluded from their visual display. Despite such intuitively appealing findings, there were methodological limitations associated with all three studies, such as the potential use of peripheral vision (North et al., 2009) and the possibility that occlusion of film displays may also erase important form based cues as well as relational information (Williams et al., 2006). To this end, and by presenting only the relative motion information between the central offensive features, more direct evidence has been provided to suggest that this is the minimal essential information skilled participants encode when making familiarity-based judgments to dynamic, interactive stimuli.

Dittrich's (1999) Interactive Encoding Model purports that when attempting to recognise familiarity within dynamic sequences, skilled performers rely upon the relational information between features. More specifically, and in lieu of the current findings (as well as the previous chapter), it appears that the critical information encoded during the initial low-level bottom-up stage is conveyed as a function of localised relative motion information between key features, and their associated higher order strategic information. Skilled performers then engage in a top-down matching process, where these relations are matched against a high-level internal template/cognitive representation, which facilitates successful pattern-recognition. Similarly, the pre-processing stage in Wong and Roger's (2007) recognition of temporal patterns theory, suggests that skilled performers extract functional relations between a limited number of display features, which is sufficient to ensure accurate matching against templates stored in memory in a subsequent phase of the pattern-recognition process. Taken together, these observations are actually contrary to the conclusions drawn by Diaz, Fajen, and Phillips (2012) and Huys et al. (2008, 2009) who argue that skilled performers encode global as opposed to localised information when anticipating an opponent's actions. However, the tasks employed in these examples comprised of intra-individual relative motions for skills more closed in nature (penalty kick in soccer and different shots in tennis), whereas the task in the present study involved inter-individual relationships in a more open and interactive domain. In this regard, and while encoding relative motion information appears to be a critical perceptual process for recognising patterns in both contexts, the precise nature through which this is conveyed (i.e., global vs. local relative motions) may vary as a function of the task constraints (i.e., intra vs inter-individual relationships or closed vs. open tasks).

The main effect for display showed how participants demonstrated their most accurate recognition accuracy for Condition 3, where the two central attacking players as well as the player in possession of the ball were presented. A logical explanation for these results pertains to the increased amount of information available to the performer during scene perception, when compared to Conditions 1 and 2. Given the extensive occlusion procedures employed, this supplementary source of information feasibly gained added significance to facilitate recognition judgments for both skill groups. Chapter 2 however, controlled for this and provided evidence to suggest that pattern-recognition expertise is not necessarily constrained by the absolute amount of information present within the visual display, rather, the relative motion information between certain players within these action sequences (as demonstrated by the difference in performance for dynamic and randomised conditions),. The data in the current study builds upon this research to provide a more focussed insight into the exact nature of this information. More specifically, the localised relative motions between central attacking players appears to be the minimal essential information constraining successful familiarity judgments. Nevertheless, the addition of another feature (i.e., the ball) against which key relations can be judged relative to, appears to provide supplementary information which enhances pattern-recognition further still. This fits nicely with extant literature in the field, with eye-movement data from the work of North and colleagues (2009) providing evidence to suggest that an important task early in each action sequence is to locate the position of the ball since most information is likely to be relative to its position on the field. After location of the ball had been detected, skilled players were less guilty of 'ball watching' preferring to focus their gaze more broadly on the positions and movements of players 'off the ball', most commonly the central offensive players. In contrast, the less skilled players tended to focus solely on the player in possession of the ball, seemingly unaware of the 'greater picture' evolving in front of them.

The importance of quickly locating a central organising feature around which other features are likely to be encoded relative to, has also been demonstrated in non-sporting domains. For example, in early research by Dittrich and Lea (1994) participants were required to detect intentionality in dynamic displays and they found intentionality was most easily recognised when both 'target' and 'goal' features were present. When the 'goal' feature was removed, although participants could still recognise intentionality, their ability to do so was impaired. The information contained in the dynamic motions of the 'target' feature was sufficient to perceive and recognise intentionality, yet the presence of an additional 'goal' feature to judge this information against enhanced observers' ability to recognise the display. Charness and colleagues (2001) reported similar findings in the domain of chess, demonstrating how in check detection situations, the 'King' becomes a central organising feature with experts then making 'visual pivots' between other salient pieces to facilitate accurate pattern perception and inform their next move. The current study has provided evidence that the presence of localised relative motions between central attacking players provided the minimal essential information to recognise patterns. However, the addition of an extra feature provided an anchor against which these relative motions could be organised and enhanced participants' ability to complete the perceptual-cognitive process of pattern-recognition.

In summary, the use of PLD action sequences served to emphasise how skilled participants initially encode relative motion information between display features to recognise patterns in interactive displays comprising of multiple independent objects. By occluding approximately *90%* of the display features, the data suggests that certain localised micro-patterns contain the minimal essential information that is necessary to recognise more global patterns. Specifically, the central offensive players, while recognition accuracy improved further still with the addition of the player in possession. Additional evidence has therefore been provided to support Dittrich's (1999) interactive encoding model as well as Wong and Rogers's (2007) recognition of temporal patterns theory. Findings also have important implications for those interested in identifying the mechanisms governing expertise (see Dittrich, 1999; Ericsson & Kintsch, 1995; Williams & Ericsson, 2005), while providing a conceptual backdrop for the type of training that could be used to facilitate performance enhancement in this area (see Williams & Grant, 1998). With previous research typically revealing a decrement in recognition performance when using PLD clips (e.g., Williams et al., 2006; North et al., 2009; 2011), an interesting area of further work would be to repeat the current study using normal video action sequences, to determine the comparative skill-based differences when participants have access to other perceptual-cognitive discriminators, such as postural cue usage. Another avenue for potential investigation would be to examine whether a domain's task characteristics constrain the critical perceptual information that underpins successful performance on the task (see Roca, Ford, McRobert, & Williams, 2011; 2013).

# Chapter 4: The Relative Importance of Different Perceptual-Cognitive Skills during Anticipation

## Abstract

The aim of this chapter was to examine whether anticipation is underpinned by the perception of inter-individual (between participants; pattern-recognition) or intra-individual (within participant; postural cues) relational information. An additional goal was to explore the effect of situational task constraints on both pattern-recognition and postural cues by manipulating the distance between the ball and the participants. An anticipation paradigm was employed presenting skilled and less-skilled players with a series of structured, offensive patterns of play in video and PLD format. The halfway line was used as a reference point to divide action sequences into a near and far viewing perspective. Skilled players demonstrated superior anticipation performance regardless of display condition, providing evidence to suggest that pattern-recognition and postural cue usage contribute to anticipation. Nonetheless, the Skill x Display interaction revealed that the skill advantage was exaggerated in the video condition, inferring that skilled players make better use of postural cues when available during anticipation. With regards to the impact of situational task constraints task on performance, when the participants were closer to the ball (near task), anticipation was more accurate for the video than PLD clips. In contrast, there was no difference between viewing conditions when the ball was further away (far task). Evidence was therefore provided to suggest that postural cue information is the primary perceptual-cognitive skill facilitating anticipation when the ball is in close proximity to the observer, whereas the two sources of information appear not differ in importance when the ball is a greater distance away. In sum, evidence was provided of the relative interaction between the different perceptual-cognitive skills during anticipation performance with the relative importance of pattern-recognition and postural cues varying as a function of the task constraints and relative availability of perceptual information.


**Keywords:** *Expertise; Pattern-Recognition; Postural Cues, Task Constraints, Anticipation*

Perceptual skills play a fundamental role in the performance of everyday activities, from driving (Mckenna & Horswill, 1999) to reaching and grasping tasks (Goodale & Servos, 1996), as well as more specialised domains, such as military (Endsley & Smith, 1996) and medical tasks (Sowden, Davies & Roling, 2000). Whether on a chaotic battlefield or busy motorway, individuals inherently perceive the intention of others to guide subsequent behaviour. This process is commonly known as anticipation and can be described as the ability to predict what is likely to happen prior to the event itself (Williams & Ward, 2007). Researchers have indicated that one of the underlying mechanisms of skilled anticipation is the capacity to use early visual information within the perceptual display to facilitate responsive actions. In the sporting domain this would appear crucial to successful performance, where the speed of the play and temporal constraints, often necessitate decisions to be made in advance of an opponent's action, these include; the batsman in cricket (e.g., Abernethy & Russell, 1984), the return of serve in tennis (e.g., Jones & Miles, 1978, Rowe & Mckenna, 2001; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996) and the penalty kick in soccer (e.g., Williams & Burwitz, 1993; McMorris & Hauxwell, 1997).

Over recent years there has been significant interest in identifying the skills and mediating processes that contribute to superior anticipation and decision-making in sport (e.g., Starkes & Ericsson, 2003; Williams & Ford, 2008; Roca et al., 2011; 2013). Although there remains controversy in the literature as to the exact causal mechanisms facilitating expert performance (Williams & Ericsson, 2005; Williams & Ward, 2007), it is widely believed that due to extended engagement within a domain, skilled performers develop a range of perceptual and cognitive skills, enabling them to use vision and other senses to identify and extract the most meaningful information in the environment for integration with existing knowledge to select and execute decisions (e.g., Abernethy, 1987, 1993; Starkes & Allard, 1993; Williams et al., 1999). A growing body of literature now exists regarding the importance of these perceptual-cognitive skills in determining performance proficiency (Williams et al., 1992). According to many researchers, a particularly important process facilitating expert anticipation in team sports, is the ability to recognise familiarity or patterns between features within a display (e.g., Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor 1996; Abernethy et al., 2005; Williams et al., 2006; Williams et al., 2012). The previous two chapters examined this issue in greater detail in an attempt to identify the exact nature of information underlying skilled pattern-recognition in the game of soccer. As a brief overview, findings suggest skilled defenders rely on the relative motion information between central offensive players as well as the player in possession of the ball, when making familiarity-based judgments to dynamic, interactive stimuli.

The ability to perceive and recognise familiarity is considered to be a central component of anticipation in team-ball sports (Abernethy et al., 1994; Imwold & Hoffman, 1983; Williams & Davids, 1995). It is proposed that when performing within their field of expertise, skilled performers can quickly extract relations between features (i.e., players' positions and movements), which allow them to recognise an evolving pattern of play sequence earlier in its evolution, enabling them to successfully anticipate the end result of that sequence (e.g., Williams & Davids, 1995). A contrasting argument is that recognition is a by-product of extended experience within a particular domain. Therefore, while recognition might provide an indication of the domain specific knowledge held by a performer, it does not directly contribute to, nor is it predictive of, anticipation (see Ericsson & Lehmann, 1996).

As discussed in earlier chapters, North et al. (2009) tested the latter argument by recording eye movement data while participants completed both anticipation and recognition paradigms. Performance on anticipation and recognition tasks were moderately positively correlated ($r$ = .39, $p$ = .06) and skilled participants showed no differences in their fixation transitions between key display features across both tasks, which indicated a broad relationship-based perceptual strategy for both anticipation and recognition. However, a number of differences emerged as participants made more fixations of a shorter duration to more locations when anticipating compared with recognising.

In a follow-up study, North et al. (2011) recorded verbal reports across the two tasks and reported similar findings. Anticipation and recognition performance were moderately positively correlated ($r$ = .42, $p$ = .07), however participants verbalised more evaluation statements when anticipating, indicating that they were utilising more complex memory representations when completing this task. The results from both experiments indicate that anticipation and recognition share a number of common processes, yet the precise mechanisms underpinning each task differ somewhat.

Anticipation, like expertise itself, has been shown to be dependent on a range of perceptual-cognitive skills, with the relative importance of each varying as a function of the constraints of the task environment (e.g., Newell, 1986). Moreover, researchers believe that they are not mutually exclusive and interact dynamically with each other during performance (Williams & Ward, 2007). This in itself highlights an unfortunate limitation of traditional paradigms and their reductionist approach to capture and examine each perceptual-cognitive skill in isolation, with stronger emphasis on experimental control rather than ecological validity or representative task design (Williams, 2009). The current programme of work has focussed exclusively on the minimal essential information underlying pattern-recognition skill, with this particular perceptual-cognitive skill considered crucial to contexts involving multiple individual features (e.g., soccer and chess). In many situations however, and typically for more closed skills (e.g., facing a smash in badminton or a penalty kick in soccer), the pick-up of postural cues from an opponent's body movements ahead of a key event is considered key to facilitate anticipation judgments (e.g., Franks & Hanvey, 1997; McMorris & Colenso, 1996; Savelsbergh, van der Kamp, Williams, & Ward, 2005). It has been proposed that experts perceive and process an isolated postural cue to predict their opponent. For example, the penalty kick in soccer has received a significant amount of research with both self-reports and eye-tracking data providing evidence to suggest that expert goalkeepers pick up information from the non-kicking foot when attempting to anticipate shot direction (e.g., Savelsbergh et al., 2002; 2005).

More recent evidence however, suggests that postural cue usage itself involves pattern-recognition as the critical information emerges from the relationships and interactions between multiple postural cues, as oppose to an isolated body part. For example, Diaz et al. (2012) examined whether the information used to anticipate penalty kick direction in soccer, is best characterised as local to a particular body segment or distributed across multiple segments. Using data from a series of experiments, evidence was provided to suggest that anticipatory judgments were based on distributed information across the body rather than localised to a particular limb segment, such as information relating to the hip and location of foot-to-ball contact. Similar findings pertaining to the experts' sensitivity to distributed patterns of movement information across an opponents' body parts, have also been observed in tennis (Huys et al. 2008; 2009) and rugby (Brault, Bideau, Kulpa, & Craig, 2012), respectively. It therefore appears that pattern-recognition may underpin advance cue utilisation, the critical distinction being that such information is conveyed as a function of intra-individual rather than inter-individual patterns (see Brault et al., 2012; Diaz et al., 2012; Huys, Smeeton, Hodges, Beek, & Williams, 2008). When attempting to anticipate situations in the open and dynamic game of soccer, the performer is exposed to both the individual who is making the pass (i.e., potential intra-individual pattern information) and the positions and movements of teammates and opponents around them (i.e., potential inter-individual pattern information). In order to identify the specific processes underpinning superior performance in these contexts, an important issue to consider is the relative contribution each of these perceptual-cognitive skills makes to anticipation and how this may vary as a function of the task.

Roca and colleagues (2013) addressed this issue by examining the role of, and interaction between the different perceptual-cognitive skills underlying anticipation and decision-making in soccer. Participants assumed the role of a central defensive player and interacted with a full-sided display from the first-person perspective as they completed anticipation and decision-making paradigms. They were required to make movement-based responses similar to the real-world setting, while eye movement and verbal report data were collected. Action sequences were also presented from a near and far viewpoint, with the ball located in either the offensive or defensive half of the pitch (relative to the viewer), to examine the effect of task constraints on process measures and performance. As predicted, skilled players were more accurate than their less skilled counterparts at anticipating their opponent's and deciding upon an appropriate course of action. More interestingly however, eye-movement and verbal report data varied as a function of the task constraints. Skilled players employed more fixations of shorter duration toward a greater number of locations in the display when interacting with the far compared with the near task condition. This was attributed to their tendency to identify familiarity and structural relations between features, such as the positions and/or movement patterns of players when viewing the action from afar (e.g., North et al., 2009; 2011). For the near task situation, they made fewer fixations of longer duration, mostly toward the player in possession of the ball and not disparate areas of the pitch.

For the verbal report analysis, skilled players made more references to recognition of structure or patterns within evolving sequences of play when viewing the far task situations. For the near task, they engaged in more predictive and planning statements pertaining to the postural orientation of opponents and team-mates, followed by expectations as to what their opponents were likely to do in advance of the event (situational probabilities). Taken together, findings from the complementary process tracing measures highlighted the potential for interaction between the different perceptual-cognitive skills, with skilled players more proficient at adapting their visual search and cognitive processing strategies in relation to the distinctive constraints of the task (Ericsson & Lehmann, 1996; Williams et al., 2011). Specifically, and for more distal tasks, findings demonstrated how the recognition of patterns between players may make a relatively larger contribution to anticipation. In contrast, and for more proximal tasks (where the ball is closer to the observer), the relative influence of recognising patterns between players is diminished, with postural cue usage becoming more important.

The following study builds on the work of Roca and colleagues (2013) to further examine the extent to which pattern-recognition and postural cues contribute to anticipation, and how their relative importance may vary as a function of the task constraints. Previously, researchers (e.g., North et al., 2009, 2011) have indicated expert recognition is underpinned by perceiving relationships between display features. However, visual search (North et al., 2009) and verbal report (North et al., 2011) data suggest some differences in the processes underpinning anticipation and recognition tasks. The current study was therefore designed to provide a more direct measure of whether skilled performers are able to accurately anticipate solely on the basis of domain-specific patterns. In comparison to Roca et al. (2013), a number of alternative methodological approaches are implemented, specifically relating to the nature of the action sequences employed, as well as the absence of process tracing measures. In this regard, participants anticipated final pass destination of the player in possession to action sequences presented from the third person perspective. This is a significant modification with researchers demonstrating how display perspective can influence perceptual-cognitive skill in dynamic team games. For example, Mann, Farrow, Shuttleworth, and Hopwood (2009) examined the decision-making ability of skilled youth soccer players on a film-based task, and found that participants were more accurate when viewing the action from a third person aerial standpoint in comparison to the first person view. Despite being less representative of a players' normal perspective, they attributed these findings to the additional specifying information available from this outlook, affording the participants with an enhanced perception of depth and space, as well as a greater appreciation of the movement and positions of the attackers and defenders. Consequently, the third person viewing perspective employed in the present study will not only provide interesting comparisons to the work of Roca and colleagues (2013), but it will also maintain clip uniformity across earlier experiments in the current programme of work.

In conjunction with an alternative viewing perspective, participants were required to make anticipation judgments to two different clip types; video or point-light display (PLD). As evidenced in the previous chapter, the latter condition depicts the location and movement of the players and ball as points of light against a black background, within an outline of the field. In the absence of process tracing measures, it is envisaged that these two clip types will provide an appreciation of how the different perceptual-cognitive skills interact when making anticipation judgments to dynamic soccer stimuli. In this regard, the normal video clips display both relational and postural information, whilst in addition to superficial display features (i.e., uniform color, environmental conditions), PLD may remove other, potentially meaningful information, namely postural cues. Therefore, in PLD stimuli all that remained was inter-individual relational information between features. If perception of inter-individual relational information was central to anticipation, as it is to recognition (c.f., Williams et al., 2012), skilled participants were expected to outperform their less-skilled counterparts for both film and PLD conditions. In contrast, if skilled participants utilise postural cues (i.e., intra-individual relational information) rather than relations between features to anticipate, a Skill x

Display interaction was envisaged, with skilled participants showing superior anticipation in the film condition only.

A second aim was to extend the findings reported by Roca et al. (2013) by examining how the relative contribution of inter-individual relations between display features and intra-individual relations between postural cues may vary as a function of the task constraints. The film and PLD stimuli were divided equally into two different task conditions. When the final pass in the action sequence was made before the halfway line, these were considered far in nature, whereas those executed in the defending team's half were deemed near. Based on the findings of Roca et al. (2013), it was predicted that for the far task situations, pattern-recognition would be a more important perceptual-cognitive skill and therefore more accurate anticipation would be observed for skilled participants compared to less-skilled in both film and PLD conditions. However, for the near task situation pattern-recognition was expected to be less crucial, with the perception of postural cues hypothesised to be a more important perceptual-cognitive skill. Consequently, skilled participants were expected to outperform their less-skilled counterparts for film stimuli, but that this advantage would be lost for PLD stimuli as postural information is removed.

## Method

### Participants

A total of 12 skilled and 12 less skilled male players participated. Skilled participants (*M* age = 22.1 years, *SD* = 3.2) had previously played at a professional club's Academy and/or were currently playing at a semi-professional level and all played in defensive positions. These participants had been playing soccer competitively for an average of 14.0 years (*SD* = 2.5). In contrast, less skilled participants (*M* age = 21.7 years, *SD* = 2.9) only played soccer at a recreational or amateur level and had been participating for an average of 10.5 years (*SD* = 3.3). All participants reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of Liverpool John Moore's University. Participants provided informed consent and were free to withdraw at any stage.

### Test Stimuli

Participants were required to make anticipation judgments to action sequences presented in both video and PLD format. The video test included structured sequences of play taken from the same battery of clips used in Chapter 2, such that the filming position and rating protocol were the same as outlined in the methodology of Chapter 2. Similarly, and for ease of comparison between the test films, the PLD clips were edited versions of the abovementioned video action sequences using the same technique as described in Chapter 3. In addition to video and PLD format, action sequences were divided into near and far perspective to examine the effect of task constraints on anticipation performance. As described previously, when the final pass in the action sequence was made before the halfway line, these were considered 'far' in nature, whereas those in which the final pass was made in the defending teams half, were deemed 'near' (see Figures 4.1 to 4.4).

Figure 4.1: Example video action sequence from a far task situation.

Figure 4.2: Example PLD action sequence from a far task situation.

Figure 4.3: Example video action sequence from a near task situation.

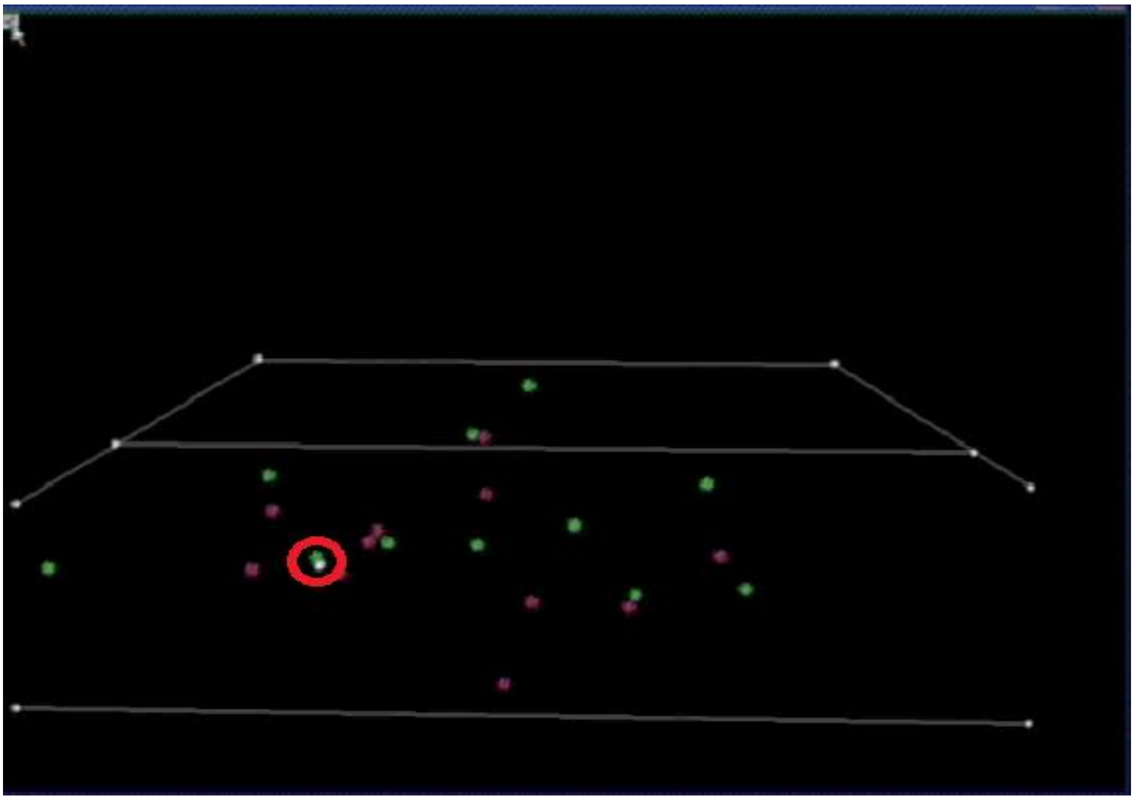

Figure 4.4: Example PLD action sequence from a near task situation.

The testing was undertaken in two separate sessions with participants firstly making anticipation judgments to the video test, which was followed by a practice history questionnaire and then the PLD test. In each paradigm 24 action sequences were presented, including 12 from a far perspective and 12 from a near, which were randomly ordered throughout. The clip would start in either the attacking or defending half of the pitch (depending on task situation) and be occluded at the point of 'foot-ball' contact when the player in possession of the ball was about to make a penetrative pass to another team-mate. The ball would travel forwards and develop play for the offensive team, as oppose to a backwards or sideways pass. The participants would then anticipate final pass destination using a pen and paper response. The exact same process was employed for the PLD test where clip order was counter balanced to prevent familiarity effects, and kept constant across participants.

**Apparatus**

The apparatus used to convert the action sequences into PLD format, and present the two test films, were the same as described in the methodology of Chapters 2 and 3, respectively.

**Procedure**

Participants were tested individually and sat in a chair 3-metres from the projection screen such that the image subtended a viewing angle of approximately 40-degrees. They were informed that they would be presented with a series of soccer clips showing sequences of play in two different display formats; video and PLD. Participants were instructed that each clip would last for 7-seconds and would occlude when the player in possession of the ball was about to make an attacking pass to another team-mate. At this moment, it was explained that a freeze-frame of the action would be shown to give them a chance to anticipate final pass destination.

Participants circled the player they thought would receive the ball on a schematic representation of the pitch, using a pen and paper response. Such a method is commonly employed when investigating sports expertise, yet it is acknowledged that participants may extract additional information when the final frame is 'frozen' over and above that extracted during the action sequence (see Ryu, Abernethy, Mann, & Poolton, 2015). Participants however, were not provided with a pre-determined list of anticipation options in an attempt to ensure they could unambiguously select their response from all the information available in the display. Moreover, findings reported by Borgeaud and Abernethy (1987) and Williams et al. (2012) suggest that participants extract minimal information from static displays compared to dynamic sequences. Following the 7-second sequence, the image on the screen occluded to black, whereupon there was an inter-trial interval of five seconds before the next clip commenced. Prior to testing, participants were presented with three familiarisation trials. After presentation of the video test film, there was a 10-minute break during which participants completed a practice history questionnaire. They were then asked to view a second series of clips in PLD format, where they once again had to anticipate final pass destination using the exact same procedure as the video test. A brief familiarisation procedure was employed prior to commencing the paradigm where the concept of PLDs was fully explained to participants, with three practice trials presented.

**Data Analysis**

Anticipation performance was obtained by dividing the number of correct responses by the total number of trials and multiplying by 100 to create a percentage accuracy score. Responses were marked as correct or incorrect based upon whether participants highlighted the actual player who received the ball. Due to the limited number of PLD clips available, it was not possible to measure anticipation accuracy using the signal detection measures of sensitivity (*d*') and response bias (*c*) as evidenced in Chapter 2 (Green & Swets, 1966). As such, scores were analysed using a mixed design 3-way analysis of variance (ANOVA) in which the between-participants factor was skill (skilled vs. less skilled) and the within participants factors display (PLD and video) and task situation (near and far).

Prior to running each analysis, the data were tested for normality using a Shapiro-Wilks test. Partial eta squared ($\eta_p^2$) values are provided as a measure of effect size for all main effects and interactions. Cohen's *d* measures are reported where two means are compared. For repeated measures ANOVAs, violations of sphericity were corrected by adjusting the degrees of freedom using the Greenhouse Geisser correction when the sphericity estimate was less than 0.75, and the Huynh-Feldt correction when greater than 0.75 (Girden, 1992). The alpha level for significance was set at $p$ <.05.

## Results

ANOVA revealed a significant main effect for skill; $F_{1, 22}$ = 77.920, $p$ < .01, $\eta_p^2$ = 0.780. Skilled participants (*M* = 58.33 %, *SD* = 18.2) were more accurate at anticipating final pass destination of the player in possession of the ball than their less skilled counterparts (*M* = 36.11 %, *SD* = 10.36), *d* = 1.501. There was a main effect of display on anticipation accuracy; $F_{1, 22,}$ = 39.707, p < .01, $\eta_p^2$ = 0.643. Participants performed more accurately on the video film (`*M* = 53.82 %, *SD* = 19.37) when compared to the PLD clips (*M* = 40.63 %, *SD* = 15.05), *d* = 0.760. There was a significant Skill x Display interaction, $F_{1, 22,}$ = 15.840, $p$ < .01, $\eta_p^2$ = 0.419. Although skilled participants' anticipation accuracy was significantly better than less-skilled for both the video film and PLD clips, this advantage was substantially enhanced for film (*M* = 69.10 %, *SD* = 13.57 vs. *M* = 38.54 %, *SD* = 9.77 respectively), *d* = 2.58, compared to PLD clips ($M$ = 47.57 %, $SD$ = 15.83 vs. $M$ = 33.68 %, $SD$ = 10.56 respectively), $d$ = 1.03. This interaction is illustrated in Figure 4.5.

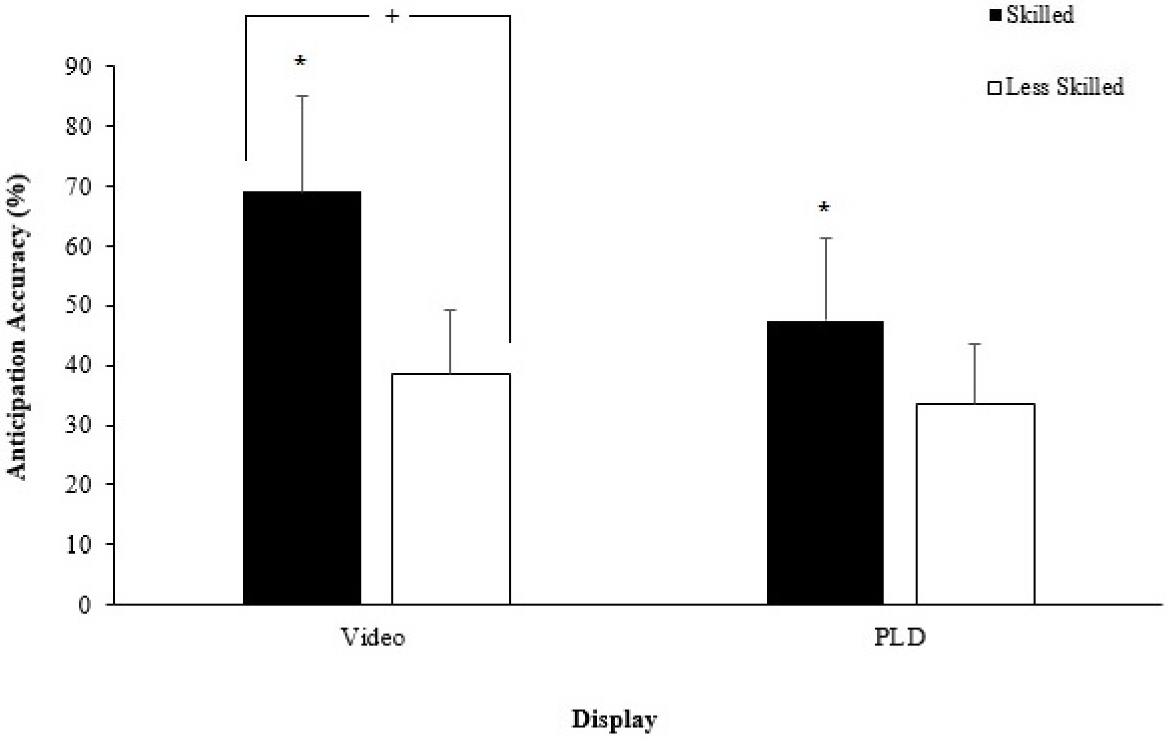


Figure 4.5: The Skill x Clip Type interaction (with SD bars) for anticipation accuracy. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

There was a significant main effect for task situation on anticipation accuracy, $F_{1, 22,}$ = 31.118, $p < .01$, $\eta_p^2$ = 0.586, as participants demonstrated better anticipation accuracy on the far task ($M$ = 52.95 %, $SD$ = 18.13) compared to the near task situations ($M$ = 41.49 %, $SD$ = 16.97), $d$ = 0.653. ANOVA revealed a significant Task Situation x Skill interaction, $F_{1, 22,}$ = 8.257, $p < .01$, $\eta_p^2$ = 0.273. Skilled participants made significantly more accurate anticipation judgments than less-skilled participants in both far and near tasks, however their advantage was significantly greater in the far task ($M$ = 67.01 %, $SD$ = 13.79 vs. $M$ = 38.89 %, $SD$ = 9.08

respectively), *d* = 2.41, compared to the near task (*M* = 49.65 %, *SD* = 18.14 vs. *M* = 33.33 %, *SD* = 10.99 respectively), *d* = 1.09. This interaction is illustrated in Figure 4.6.

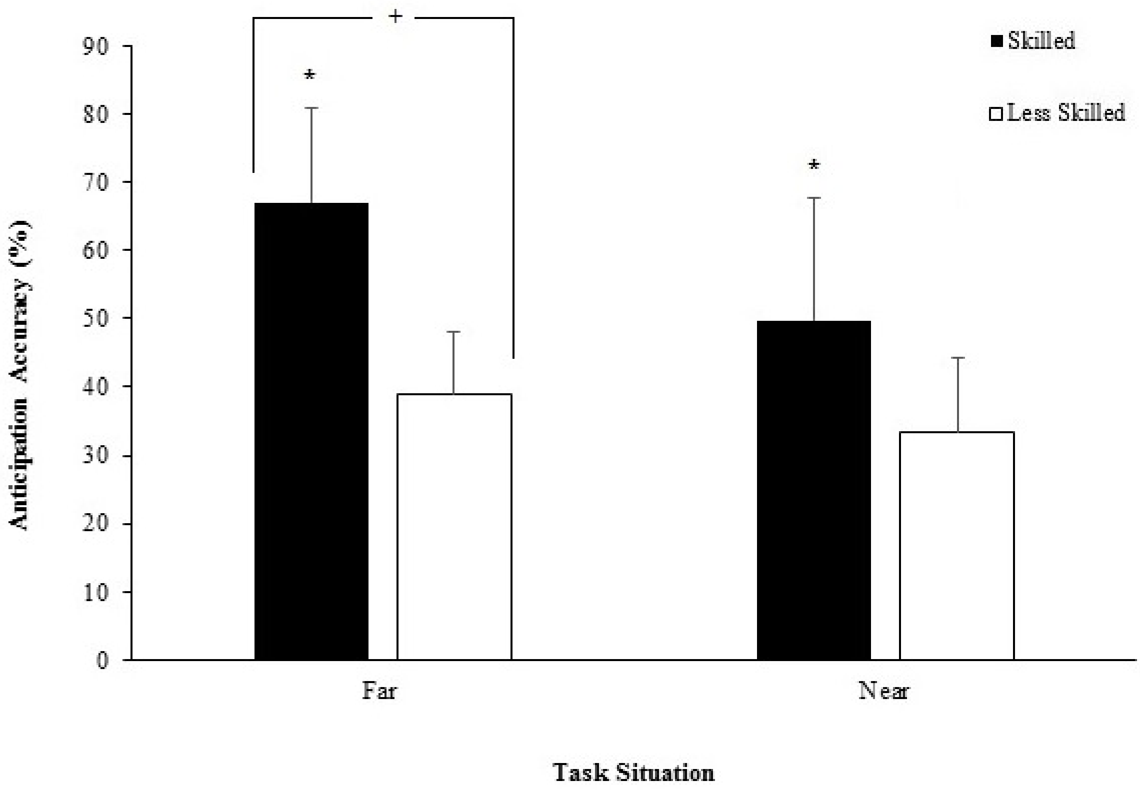


Figure 4.6: The Skill x Task Situation interaction (with *SD* bars) for anticipation accuracy. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

The Task Situation x Display interaction proved to be significant, $F_{1,\ 22,} = 9.659$, $p < .01$, $\eta_p^2 = 0.305$. For the video film clips, participants showed no difference in anticipation accuracy between far and near tasks (M = 56.60 %, SD = 21.28 vs. M = 51.04 %, SD = 17.26 respectively), *d* = .287. However, for PLD clips participants were more accurate in their anticipation judgments for the far than near task (M = 49.31 %, SD = 14.31 vs. M = 31.95 %, SD = 10.03 respectively), *d* = 1.405. This interaction is illustrated in Figure 4.7. Finally, the Distance x Clip Type x Skill interaction was not significant, $F_{1,\ 22,} = 1.637$, $p > .05$, $\eta_p^2 = 0.069$.

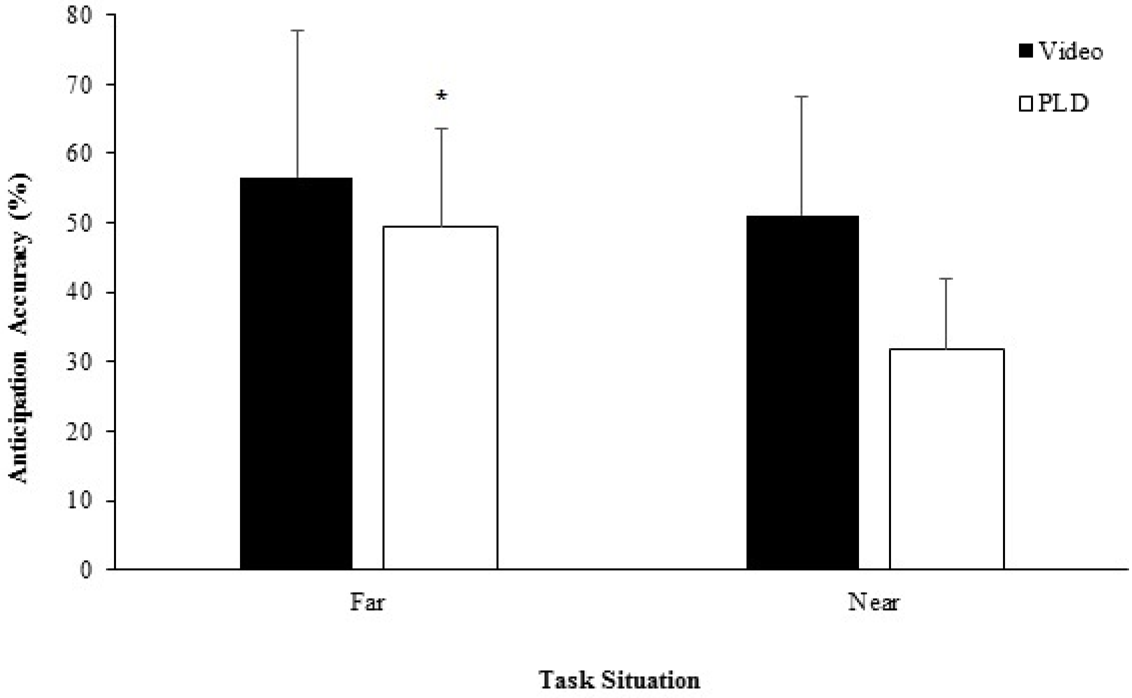


Figure 4.7: The Clip Type x Task Situation interaction (with *SD* bars) for anticipation accuracy. * Significant differences between experimental conditions. + Significant differences in scores collapsed across experimental condition.

## Discussion

The principal aim of the study was to examine the relative importance of pattern-recognition and postural cue usage when attempting to anticipate temporally constrained soccer stimuli. A secondary goal was to investigate whether their relative importance was dependent on the situational task constraints, with participants making anticipation judgments in near or far proximity to the ball.

Findings revealed a main effect for skill irrespective of display ($d$ = 1.501) supporting existing literature regarding expertise differences for anticipation proficiency in soccer (e.g., Helsen & Starkes, 1999; Vaeyens, et al., 2007a, b; Williams & Davids, 1998). This advantage is believed to be a result of the extended hours of deliberate practice engaged in by highly skilled performers (Ericsson et al., 1993), which facilitates the development of elaborate task-specific knowledge structures that allows them to encode, retrieve and process information in a more efficient and selective manner (e.g., Abernethy & Russell, 1987). This subsequently affords experts with a significant advantage over novices when attempting to represent the current situation and identify the likely future outcomes (see Ericsson & Kintsch, 1995; Ericsson et al., 2000).

Typically, researchers examining the nature of information underlying expert anticipation, have used normal video film footage, which contains information from both intra-individual postural cues and orientations of players as well as inter-individual relations between the multiple players (i.e. pattern-recognition). By revealing a skill effect regardless of display, evidence has been provided to suggest that the inter-individual relational information between display features that is crucial when making familiarity judgments (see North et al., 2009, 2011; Williams et al., 2006, 2012), is also an important source of information when anticipating event outcome. When considered alongside previous findings investigating stimulus recognition (North et al., 2009, 2011; Williams et al., 2006, 2012), the data reported here infer that the same processes (i.e., inter-individual relations) contribute to skilled anticipatory judgments. It is proposed that with a greater appreciation for the positions and relative orientations of the offensive players, skilled players are able to recognise patterns of play earlier in their evolution, thereby facilitating anticipation judgements (e.g., Williams & Davids, 1995; Abernethy et al., 1994; 2005; Imwold & Hoffman, 1983).

The Skill x Display interaction observed demonstrates that while skilled participants were more accurate in both display conditions, this advantage was significantly greater when anticipating video film sequences ($d$ = 2.58) than PLD clips ($d$ = 1.03). Thus, and although the large effect size for PLD clips supports the argument that skilled players can anticipate successfully by using pattern-recognition skill, the nature of the Skill x Display interaction suggests that this is not the only source of information they encode. In normal video film displays, participants have access to the same inter-individual relational information present in PLDs, yet this is supplemented with postural cues and intra-individual relations from the body positions and movements that players adopt. The increase in effect size when responding to video film displays suggests that in addition to inter-individual relationships, participants make use of advanced postural cues and the intra-individual patterns conveyed through these to anticipate event outcome. These findings concur with previous research of a similar ilk, most notably the work of North and colleagues (2009; 2011), who found performance of skilled players on respective anticipation and recognition tasks to be positively correlated to a moderate extent. Nevertheless, and while similarities between visual search behaviour (2009) and verbal protocol analysis (2011) were reported between anticipation and recognition tasks, the process tracing measures appeared to be more complex for the anticipation tasks. Specifically, participants made more visual fixations of a shorter duration and verbalised more evaluative thoughts when anticipating.

The previous two chapters in the current programme of work have provided evidence to suggest that skilled players identify familiarity in dynamic displays by perceiving the relative motion information between central offensive players as well as the player in possession of the ball (see Williams et al., 2012). Crucially, and given the findings for the PLD stimuli in the present study, the perception of relational information between key features also appears to contribute towards anticipation. Nevertheless, skilled players were seemingly able to utilise postural cues and orientations of players and the intra-individual relational information they convey to enhance their ability to anticipate final pass destination of the player in possession of the ball, as evidenced by the Skill x Display interaction. This in itself is not a novel finding, with other studies of a similar ilk also observing a decrement in performance when footage is presented in PLD format and contextual information removed (e.g., Williams et al., 2006; North et al., 2009; 2011). It does however emphasise the complexity of anticipation, which is likely to comprise of a number of perceptual-cognitive skills (see Williams & North, 2009) that interact dynamically during performance (Williams, 2009).

With regards to the less skilled players, superior performance was envisaged for the video action sequences as a result of their reliance on superficial display features (e.g., Williams et al., 2006). While the descriptive statistics supported this, the difference between the two test films was not significant. Moreover, their anticipation scores were generally very low relative to the skilled players ($d$ = 1.501), making it difficult to draw exact conclusions about the nature of information encoded when making anticipation judgments. According to the LTWM Theory (Ericsson & Kintsch, 1995; Ericsson et al., 2000), skilled individuals develop elaborate task-specific retrieval structures as a result of extended deliberate practice, which facilitates better indexing and organisation of information at encoding. In contrast, less skilled players have fewer and/or less refined representations in long-term memory, and are thus impaired in their ability to not only pick-up, but also attribute meaning to any relational and/or postural cue information in the presented stimuli. Consequently, they adopt a less sophisticated, low-level processing strategy focusing on more discrete or superficial elements when encoding the display, which may account for their guesswork approach in the current study.

Having provided evidence to suggest the both pattern-recognition and postural cue usage contribute towards anticipation, a secondary aim was to examine the relative importance of these as a function of the situational task constraints. The halfway line was used as a reference point to separate action sequences into a near and far viewing perspective. Based on the process tracing measures reported by Roca et al. (2013), it was envisaged that for the far task situation, skilled participants would rely primarily on pattern-recognition skill and the relational information between features, and would therefore be more accurate at anticipating event outcome regardless of display. For the near task situations however, skilled participants were only expected to demonstrate an advantage for the video film clips (where information from postural cues and body shape is maintained). In contrast, no differences between skill groups were hypothesised for the PLD sequences with potentially important postural cues removed from the display.

The reported data partially supported these hypotheses. A significant Distance x Display interaction was observed which showed that when anticipating in the far task, participants were unaffected by whether the sequence was shown in video film or PLD. In contrast, participants were significantly better at anticipating video film than PLD sequences in the near task. In line with predictions, it was subsequently concluded that the specific perceptual-cognitive skills facilitating anticipation is underpinned by the situational task constraints. To this end, and in situations where the performer is far away from the action or ball, pattern–recognition and the inter-individual relational information between display features appear to be more important. Yet when the action becomes more localised and time-constrained, the results suggest that postural cues and the intra-individual relational information between these cues, gain greater significance in order to guide anticipatory decisions, given the relative drop-off in performance for the PLD clips. Interestingly however, and contrary to predictions, these results were not affected by participant skill level.

Despite contrasting methodologies, findings from the present study fit nicely with the skill-based differences observed for the process tracing measures undertaken in the Roca et al. (2013) research. In the far task situation skilled players made more references to the recognition of patterns within evolving sequences of play, whilst eye-movement data demonstrated how they fixated on more disparate areas of the display in a perceived attempt to identify familiarity and structural relations between features (North et al. 2011). In relation to the current study, a main effect for skill was found for both clips types in the far task situation, with pattern-recognition proficiency therefore considered to be the key perceptual-cognitive skill facilitating anticipation performance. Returning to Roca et al. (2013) and the near task situations, skilled players employed lower search rates generally focussing their gaze on the player in possession of the ball. They also made more statements relating to the postural orientation of said player, as well as those of opponents and team-mates ahead of a key event such as foot-ball contact. Whilst a main effect for skill was found for both clip types in the near task situation, the significant decrement in performance for the PLD test film provides strong support for the importance of postural cue information when the action becomes more dynamic and temporally constrained, even when the action is presented from the third person perspective.

Although the data reported here provides support for existing literature examining the relative interaction between the different perceptual-cognitive skills during anticipatory tasks, it also highlights a potential limitation relating to the third-person perspective employed, as oppose to the more ecologically valid first-person as used by Roca and colleagues (2013). An alternative interpretation of findings therefore, is rather than the relative contributions of pattern-recognition and postural cue usage (intra and inter-individual relationships) to anticipation being dependent on task constraints, it could be that in the far task participants were unable to see the postural cues due to the resolution of the display and so performance suffered relative to the near task where information from postural cues was more readily available. To more stringently test the prediction that task constraints shape the perceptual-cognitive processes employed to anticipate, researchers could replicate the design and task employed here using a first-person viewing perspective (as per Roca et al., 2013) or include an extra condition in which the far task is magnified to make information from postural cues more accessible. Nevertheless, the findings are in line with those reported by Roca et al. (2013) which suggest that the perceptual-cognitive skills and processes that individuals utilise depends on the task constraints or perceptual information to which they are exposed. The data not only supports the proposal that anticipation is multi-dimensional in nature (see Williams & North, 2009), but also suggests that the different perceptual-cognitive skill interact dynamically with each other during performance (Williams, 2009).

Another point of interest pertains to the use of situational probabilities when making anticipation judgments. Research has shown how skilled performers use knowledge stored in their long-term memory to establish more accurate and refined expectations of likely events to guide anticipation judgments. Using freeze-frames of match-play at key moments, and asking participants to highlight and rank in order of likelihood the key players in a good position to receiver the ball, Ward and Williams (2003) demonstrated how expert soccer players chose a greater number of likely event probabilities, whereas sub-elite players were less proficient in assigning a hierarchy of probabilities to the events likely to unfold. According to Gottsdanker and Kent (1978), the enhanced domain-specific knowledge structures of experts permit experts to dismiss a range of situations considered as being highly unlikely. In the absence of verbal protocol analysis in the current study, it was not possible to speculate on the relative importance of situational probabilities to anticipation performance across task conditions and clip type. While Roca et al. (2013) provided evidence to suggest that skilled soccer players use situational probabilities when the action becomes more localised and time-constrained, there is still limited research in this area, especially for team-ball games. This seems particularly pertinent for the central defender in soccer given the associated cost-benefit ratio of making inaccurate/accurate judgments, which will largely be constrained by the location of the ball (as well as opponents and team-mates). For example, when the ball is in the opposite half of the pitch, there is arguably very little cost as well as benefit in generating probabilities given the time available as the ball is far away. Conversely, when the ball/action becomes more localised and time-constrained the advantage of assigning probabilities logically increases in order to provide more time to formulate and select the most accurate response. An interesting area of investigation would therefore be to further examine how task situation affects the ability to formulate 'a priori' expectations of the potential options that might occur in any given situation.

In conclusion, the reported data provides evidence to suggest that both pattern-recognition and postural cue usage contribute towards anticipation. Although skilled participants were able to successfully anticipate using inter-individual relational information (PLD clips), performance is enhanced when this information is supplemented with postural cue information (video film). In addition, the findings demonstrate how the relative contribution of these two perceptual-cognitive skills varies as a function of the task or perceptual information available to participants. More specifically, skilled players appear to rely more predominantly on pattern-recognition skill when the object to be anticipated is further away. In contrast, and for more time-constrained and localised situations, postural cue information of opponents on and around the ball seemingly become more important when making anticipation judgments. Findings therefore provide further evidence for the dynamic interaction between different perceptual-cognitive skills during anticipation.

# Chapter 5: Training Pattern-Recognition and Anticipation Skill

## Abstract

Despite the perceived importance of pattern-recognition to high-level performance in soccer, no literature exists regarding its susceptibility to practice and instruction. An exploratory investigation was therefore conducted to compare the effectiveness of various perceptual training techniques in developing this skill. With many researchers considering the ability to recognise sequences of play as a strong predictor of anticipation skill in team-ball games, an additional aim was to examine whether potential training effects for pattern-recognition transferred to anticipation performance. A total of 64 amateur level soccer players participated, initially completing pre-training recognition and anticipation tests before being ability-matched into four experimental groups. With the exception of the control group who received no training at all, the three other groups underwent the 2-week intervention where they were exposed to various offensive sequences of action over 4-training blocks. The two guidance groups had their attention directed to specific display features by either verbal instruction or visual cues, whilst the video-only group watched the sequences with no directive cues. All groups then completed the post-training recognition and anticipation tests. Although participants were significantly more sensitive in their recognition decisions at post-test compared to pre-test, findings were confounded by the lack of Group x Training interaction, with no main effect for Group reported either. Similarly, the anticipation data revealed no main effects for Group and Training, and no Group x Training interaction. Possible reasons to account for the null effects are discussed further in the chapter.



**Keywords:** *Pattern-Recognition; Anticipation; Relative Motion; Perceptual Leaning; Visual Information Pick-up*

The relentless evolution of soccer as a contemporary business has seen it grow into arguably the largest and most ruthless entertainment industry in the world, where only a fraction of individuals reach the very peak of the sport while countless others fall by the wayside. With clubs integrating players at a very young age onto their developmental programmes, anything that may ‘fast-track’ their progression during this time would prove extremely beneficial. In recent years, a wealth of research has highlighted the importance of perceptual-cognitive skills to high-level performance in soccer (Williams & Ward, 2007). There is substantial interest at both theoretical and practical levels in finding training methods to accelerate the acquisition of these skills, to effectively shortcut the route to expertise. To this end, a stimulating question is whether it is possible to develop procedures that selectively train perceptual skill independent of physical practice. Several reviews have highlighted the paucity of work in this area, citing the need to develop more systematic programmes of research to make a greater contribution to skill enhancement in sport (Williams & Grant, 1999; Williams & Ward, 2003; Abernethy, Wann & Parks, 1998).

Increasingly, the potential contributions from other fields and professions have been explored in an attempt to improve performance in sport. For example, clinically based visual skills training programmes have been administered (e.g., ‘SportsVision’ - Wilson & Falkel, 2004). However, sports optometrists (e.g., Stine, Arterbrun, & Stern 1882; Hazel, 1995) and scientists (Abernethy, 1986; Herman & Retish, 1989) maintain there is no convincing empirical evidence to show that such programmes produce benefits that successfully transfer to sporting performance (e.g., Cohn & Chaplik, 1991; Mcleod, 1991; West & Bressan, 1996: Wood & Abernethy, 1997; Abernethy & Wood, 2001). This conclusion has subsequently lead researchers to examine whether sport-specific training packages can be developed to isolate and train the perceptual-cognitive skills that are critical in successful sporting performance.

Preliminary findings regarding the use of sport-specific perceptual training programmes have been encouraging, suggesting that such interventions may have considerable potential as a method of performance enhancement (e.g., Ward et al., 2006; Williams et al., 2004). Williams and colleagues (Williams & Grant, 1999; Williams & Ward, 2002) support such observations, concluding that although anticipation will improve through experience alone (Abernethy, 1989), perceptual-cognitive interventions designed to develop the knowledge bases underlying skilled performance have more practical utility than clinically based visual skills training programmes. The vast majority of researchers that have sought to train to anticipation have focussed on the perceptual-cognitive skill of advance cue utilisation; the ability to pick up early visual information from an opponent or teammate's body movements ahead of a key event (e.g., Müller et al., 2006; Williams & Davids, 1998). Traditionally, interventions have focussed on relatively closed situations, such as the penalty kick in soccer (e.g., Williams & Burwitz, 1993; Salvesbergh et al., 2002) or the return of serve in tennis (e.g., Farrow & Abernethy, 2002; Williams et al., 2002). For example, McMorris and Hauxwell (1997) examined the extent to which novice soccer goalkeepers could improve their anticipatory judgments after a period of perceptual training, and whether there would be a difference in learning between a group of subjects who watched 250 penalties and one that watched 500. The two experimental groups were also given written instructions regarding important pre-contact cues, such as the angle of run-up, the point of foot-ball contact and angle of the kicker's trunk at contact. In comparison to the control group who received no training, the perceptual training groups improved their anticipatory performance pre to post intervention. However, the observation of 500 penalties was no more useful than 250 penalties, which may be indicative of a cut-off point at which further observation is irrelevant.

Although improvements in anticipation performance have been reported as a result of training interventions, advance cue utilisation is not the only perceptual-cognitive discriminator influencing anticipation in sport. In line with the previous chapter of work, the relative importance of each skill has been shown to vary as a function of the task, player and situational constraints (see also; Newell, 1986; Roca et al., 2013). An obvious question therefore remains as to the trainability of other perceptual-cognitive skills assumed critical to successful sports performance. For example, Christina, Barresi, and Shaffner (1990) examined whether an outside line-backer in American football could improve their response selection accuracy after a period of perceptual training. Over a four-week period, the participant was instructed to view various domain-specific offensive scenarios and respond quickly and accurately to the cues of play by moving a joystick in the direction in which they would typically move in a real-world context. Findings revealed a significant improvement in response selection accuracy over the training intervention period; this was not however at the expense of response speed which remained the same.

Wilkinson (1992) examined the long-term retention effects of visual training in diagnosing errors in volleyball. Participants in the intervention group received traditional performance instructions supplemented with visual training which required them to discriminate between correctly performed volleyball performances and incorrectly performed responses. In contrast, participants in the comparison group received no visual training. Findings revealed how the intervention group demonstrated a long-term retention of error diagnosis, which even after a year remained significantly better than those participants who received no visual training. With researchers typically focussing on more micro-contexts (i.e. 1 vs. 1 situations) and closed-skill situations, these findings suggest perceptual-cognitive skill can be trained in more open, team-based environments. Many researchers consider pattern-recognition skill to be an important component of expertise in such contexts (e.g., Williams & Davids, 1995), where the ability to selectively attend to only the most critical display cues is crucial, as these may only be available momentarily amid potentially irrelevant information

(Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007). Surprisingly, however, there is a distinct lack of research as to whether this particular skill can be facilitated through practice and instruction (Ward & Williams, 2003; Williams & Hodges, 2005).

In order to train any perceptual-cognitive skill, researchers must be aware of the processing mechanisms that underpin it, and it is only relatively recently that researchers have begun to identify the mechanisms facilitating pattern-recognition skill in team-ball games (e.g., Williams et al., 2006; North et al., 2009). In the domain of soccer, the current programme of work has provided further evidence to suggest that skilled defenders utilise relative motion information between the central attacking players when making recognition judgments to dynamic, interactive stimuli. Consequently, and given the training effects reported for anticipation when critical perceptual cues within the display are highlighted (e.g., Ward et al., 2002), the purpose of this study was to examine whether pattern-recognition skill could be trained, by constraining the learner to focus their attention on the relative motion information between key display features.

A secondary aim was to examine how best to highlight this key perceptual information to the learner. The traditional approach is to provide detailed, explicit instructions to highlight critical contextual cues (e.g., bowler's wrist action in cricket) and explain the relationship between this information and subsequent performance (e.g., Abernethy, 1993). Significant training effects for anticipation have been reported using this approach in a variety of domains, including tennis (e.g., Williams et al., 2002; Smeeton et al., 2005) and the penalty kick in soccer (e.g., Poulter, Jackson, Wann, & Berry, 2005). Increasingly however, there has been growing awareness of the potential limitations in the use of explicit instructions and the type of learning that it may promote (Jackson & Farrow, 2005). It has been proposed that explicit instructions result in the development of consciously controlled declarative knowledge, which becomes proceduralised over time (Anderson, 1982). When required to perform in highly anxious conditions, the performer is believed to be at risk of ‘reinvesting’ back in to this declarative knowledge and completing skills under conscious control, which results in performance breaking down or ‘choking under pressure’ (Masters, 1992). As a result, researchers have begun to investigate implicit methods of instruction, which aim to facilitate learning of the skill without simultaneously accumulating the declarative knowledge base associated with explicit instructions. It is proposed that individuals who learn via these implicit methods may be more resistant to forgetting and have been shown to be more robust under the presence of stress than skills acquired explicitly (Masters & Maxwell, 2004; Smeeton et al., 2005; Abernethy, Schorer, Jackson, & Hagemann, 2012). Guided-discovery is one proposed method of implicit learning where, for the purpose of perceptual training, the aim is to direct the learner’s attention to critical areas of the display without the provision of any explicit rules to help interpret and use this information (Jackson & Farrow, 2005).

For example, Smeeton and colleagues (2005) examined the relative effectiveness of various instructional approaches in developing anticipation skill in intermediate-level youth tennis players. Performance was assessed pre, during, and post intervention, as well as under transfer conditions designed to elicit anxiety through the use of laboratory and on-court measures. Participants were separated into four experimental groups and received various levels of instruction and feedback. The explicit instruction group were directed towards key postural cues and their relationship to shot outcome. The guided-discovery group were directed towards informative areas of the display, with participants then asked how various body orientations and movements were related to shot outcome. The discovery group received no external instruction concerning the key postural cues, whereas the control group simply completed pre and post-tests. Findings demonstrated how the three training groups reduced their decision times when compared to the control group, which also transferred to the field setting, providing further support for the practical utility of perceptual training programs.

Although participants in the explicit and guided-discovery groups improved their performance during acquisition at a faster rate than the discovery group, no significant differences were reported for the relative degree of improvement demonstrated by the three training groups from pre to post-test. Moreover, and when compared to the guided-discovery and discovery learning groups, the explicit instruction group showed a significant decrement in anticipation skill for the anxiety evoking condition (Abernethy et al., 2012). It was subsequently concluded that guided-discovery methods may be the most effective training technique when time is limited (as improvements during acquisition were rapid), and performance under stressful conditions required.

The guided-discovery technique employed by Smeeton and colleagues (2005) was intended to direct attention towards key perceptual cues within the tennis action, while circumventing the need for explicit instruction to infer any meaning from this information (Jackson & Farrow, 2005). Instead, participants were asked to work out how various body orientations and movements were related to shot outcome (e.g., "Look at her hips. What do you notice about her hips and shoulders for that particular shot?"). Other commonly used techniques have involved participants estimating the velocity of the occluded action. For example, and when training anticipation skill  for the return of serve in tennis, Farrow and Abernethy (2002) asked their implicit group to judge the speed of the serve, in an attempt to ensure they did not generate hypotheses relating to serve direction. Similarly, and for a training paradigm designed to improve anticipation skill for a soccer penalty kick, Poulter and colleagues (2005) instructed their implicit group to estimate ball speed prior to the penalty being occluded, while stating how confident they were in their prediction, on a scale of 1-10. In these studies, the prediction of ball velocity was used as a means of distracting attention to a different behavioural property upon which task performance was dependent (see Svartdal, 1989; 1992).

An increasingly common guided-discovery technique is the use of colour cueing as a means of highlighting important perceptual cues in the visual display (e.g., Osborne et al., 1990), as oppose to verbalising such cues (Posner. 1980). For example, Hagemann, Strauss, and Cañal-Bruland (2006) used a transparent red patch to help orient the attention of badminton players to critical postural cues available in the hitting action of an opponent, and compared its effectiveness in developing anticipation skill to a video-only discovery group. Results showed that both the red-patch and video-only groups improved their anticipation skill from pre-test to post-test and at retention in comparison to a control group. Whilst the red-patch group demonstrated the strongest post-test to retention-test improvement, the study confirms that both video-based and attention-oriented perceptual training have clear effects on anticipating shot direction in novice badminton players.

Ryu and colleagues (2013) examined whether perceptual learning would be enhanced by supplementing normal training with onscreen visual information designed to guide the attention of novice soccer goalkeepers for a penalty-kick anticipation task. Participants were divided into one of three groups; the guided perceptual–training group received half of their trials with colour cueing that highlighted either the kinematic changes in the kicker's action, or the known visual search strategy of expert goalkeepers; the unguided perceptual-training group viewed the same clips but without any guidance, whereas the control group did not watch any of the training clips. All participants completed an anticipation test immediately before and after the 7-day training intervention, as well as a 24-hr retention test. Findings demonstrated how the guided perceptual-training group significantly improved their response accuracy for anticipating the direction of soccer penalty kicks from pre to post-intervention, which was also maintained in the retention test. In contrast, no change in performance was evident at post-test for either the unguided perceptual-training group or the control group. These observations provide support not only for the positive effects of perceptual-cognitive skill training (e.g., Williams & Burwitz, 1993), but also that interventions supplemented with guiding information may be more beneficial in enhancing anticipation skill, than those without guidance.

In another soccer-specific study, Cañal-Bruland (2009) examined the relative effectiveness of visual and verbal guidance of attention on a tactical decision-making task. Using video simulation, participants viewed 3-on-2 action sequences from the central defender's perspective and were required to decide pass direction of the player in possession of the ball. Participants were divided into four experimental groups; the visually-guided group were directed by red semi-transparent flicker cues to the most informative areas of the display, the verbal-instruction group were directed to predefined locations, the video-only group watched without any guidance, whereas the control group completed the pre and post-tests. Findings revealed post-training and retention test advantages in decision time (but not response accuracy) for groups given video training (visual and video-only) compared to groups given verbal or no training. This however was due to a significant deterioration in decision-making times in the verbal instruction condition, as performance was not statistically different for video-based training conducted with and without colour cueing.

Abernethy and colleagues (2012) also provided equivocal support for the potential value of colour cueing as a means of promoting implicit learning. Using the sport of handball, they compared the efficacy of different perceptual training approaches on an anticipation test for goalkeepers. In direct contrast to the improvements in learning found for three separate groups given (a) explicit rules to guide anticipation, (b) verbal direction toward the location of the critical anticipatory cues, or (c) an implicit pattern-matching intervention, no training effect was found for participants given colour cueing, who performed no better than the control group. These findings were consistent immediately after the training intervention and at a 5-month retention test.

Although only a very brief overview of some the literature on perceptual-cognitive skill training, the reported data presents conflicting evidence regarding the provision of guiding information when trying to improve anticipation or decision-making skill within the sporting domain (cf. Abernethy et al., 2012; Hagemann et al., 2006; Savelsbergh et al., 2010). There seems to be an evident need to conduct further research as to the most effective instructional design for conveying perceptual information to the learner. Specifically in the present study, the comparative value of colour cueing (guided-discovery), verbal instruction (explicit), and video-only (discovery) training was examined to determine whether pattern-recognition skill could be trained in the game of soccer.

A final goal of the chapter was to gain a greater insight into the potential relationship between pattern-recognition and anticipation. As reported earlier, interventions have typically focused on training advance cue utilisation, in order to improve anticipatory performance. Findings from the previous chapter however, suggest that skilled defenders are also able to use relative motion information between display features, in order to anticipate final pass destination of the player in possession of the ball. According to Starkes and colleagues (1994), pattern-recognition probes a player's ability to identify rapidly what is developing in terms of an offensive or defensive pattern of play, and thus take advantage of this awareness to anticipate what a team-mate or opponent is likely to do next. For this reason, researchers have proposed that pattern-recognition is a central component of anticipation skill in team-ball sports (e.g., Williams & Davids, 1995; Abernethy et al., 2005; Williams et al., 2006). Nonetheless, a contrasting argument posits that it is merely a by-product of extended task exposure to the specific domain, and while it may provide a reasonable indicator of the knowledge held by performers, it is not directly related to, nor predictive of, anticipation skill (e.g., Ericsson & Lehmann, 1996). As a result of this ambiguity, the present study sought to examine whether training pattern-recognition would also lead to observed improvements in anticipation, and thereby broaden our understanding of the potential relationship between the two constructs.

De Groot's (1965) seminal research in chess was arguably the first to report a potential link between pattern perception and anticipation. When recalling structured board configurations, he noted how expert players tended to describe the patterns as a function of available moves, thereby assigning a dynamic property to the pieces. It was concluded that pattern perception involves the encoding of spatial and functional relationships between elements in the visual display, allowing experts to predict future events based upon these configurations. Since this work, a range of studies has investigated the association between pattern perception and anticipation. For example, Williams and Davids (1995) employed a regression analysis technique to examine the relationship between pattern recall, recognition, and anticipation of offensive soccer action sequences. Participants comprised of experienced high-skill and low-skill players as well as physically disabled spectators (with equivalent watching experiencing). Expertise effects were found for each perceptual-cognitive skill, providing strong support for the notion that declarative knowledge is a constituent of skill rather than a by-product of experience. Findings also demonstrated how the ability to recall and recognise patterns of play were both significant predictors of anticipation skill. Although researchers have since highlighted how performance on the recall task still only explained a small proportion of the variance (Williams & Ericsson, 2005; Mann et al., 2007) subsequent research has been relatively consistent in demonstrating how pattern recall is a relatively strong predictor of anticipatory performance. For example, Farrow, McCrae, Gross, and Abernethy (2010) compared the ability of expert, intermediate, and novice level rugby-union players on their ability to recall and anticipate structured line-out patterns. Significant expertise effects were observed for recall and anticipation, while regression analyses revealed that pattern recall accounted for 40% of the variance in anticipatory skill.

Using a more open-play situation, Didierjean and Marmèche (2005) examined how experts are able to use pattern perception to facilitate anticipatory encoding in the sport of basketball. Short and long-term recognition tasks were employed as participants of varying skill levels differentiated between previously presented and new schematic patterns. Findings showed how experts were more likely to predict the next stage of play and consequently found it difficult to distinguish between game situations shown in the normal chronological order, compared to patterns shown in the reverse order. It was therefore concluded that experts encode patterns using a prospective process by incorporating the dynamic and strategy-related components of gameplay into the mental representation (Didierjean & Marmèche, 2005; see also Blättler, Ferrari, Didierjean, van Elslande, & Marmèche, 2010; Gilis, Helsen, Catteeuw, & Wagemans, 2008).

Although the findings by Didierjean and Marmèche (2005) demonstrated how anticipatory encoding is likely to play a crucial role in decision-making in sport, the use of static slides to depict a dynamic and time-constrained basketball environment could feasibly be construed as a limitation (e.g. Allard et al., 1980), and may invoke different processing demands to that of the competitive setting (Kourtzi & Nakayama, 2002). Gorman et al. (2011) examined the relative impact of movement on expert perception, by comparing recognition performance across static and moving basketball images. Findings showed how experts used a prospective encoding process when presented with schematic images, yet when these were depicted as moving videos, both expert and recreational level players based their recall more on the next likely state of the pattern rather than the final image of the pattern actually seen. It was proposed that the moving video condition contained sufficient information to allow both skill groups to elicit a prospective encoding of the patterns. In contrast, only the experts possessed the depth of knowledge required to anticipate the evolution of the schematic images. The findings therefore provided evidence of task specificity for recognition expertise, with the dynamic stimuli exaggerating the magnitude of the anticipatory response (Gorman et al., 2011). Similar observations have also been reported in soccer, with skilled players much more sensitive when making recognition judgements to dynamic action sequences rather than static images (Williams et al., 2012 - Experiment 1).

The aforementioned research was extended by Gorman and colleagues for pattern recall in basketball (Gorman et al., 2012; 2013b) and soccer (Gorman et al., 2013a), respectively. With more representative task design and novel methodological procedures, findings demonstrated how experts were more accurate in recalling patterns of play than their less skilled counterparts. Crucially, and despite being instructed to recall only the last visible location of the elements, the response patterns of experts were more closely aligned to patterns that occurred at some point in advance of the presented target configuration, with this advance being significantly further into the future than novices. The ability of experts to encode a domain-specific pattern in terms of its next likely state provides strong support for an anticipatory encoding process in the sporting domain (Didierjean & Marmèche, 2005; Gorman et al., 2011, 2012, 2013b). Although the current study focusses solely on pattern-recognition, (with fundamental differences shown to exist between the two methodological approaches; Goldin, 1978; Saariluoma, 1984), the literature on pattern perception demonstrates how experts are able to extract meaningful information from the relative location of opponents and team-mates to instinctively anticipate the evolution of the presented patterns. This fits nicely with findings from the previous chapter, which provided evidence to suggest that skilled soccer defenders are able to anticipate final pass destination of the player in possession of the ball when only inter-individual relational information between display features was presented (PLD condition). Despite these observations, the extent to which pattern-recognition directly underpins anticipation remains less clear. Of particular interest is whether they are separate processes, or is it simply the case that anticipation is a variant of pattern-recognition. This question forms the third and final aim of the current chapter, to ascertain whether potential training effects for pattern-recognition transfer to improvements in anticipation performance. From an applied perspective, if participants do not improve their anticipatory performance through the development of pattern-recognition skill, the practical value of such training interventions may be somewhat limited.

As a general overview of the study design, the performance of four different groups was compared on separate anticipation and recognition paradigms, with each test administered both before and after the training intervention. With the exception of the control group who received no training at all, the three other experimental groups were given either verbal instruction (explicit) or visual guidance cues (guided-discovery) as to which players to focus on, whilst the video-only group (discovery) watched the action sequences with no directive cues. Although there is a paucity of literature concerning the trainability of pattern-recognition skill, researchers have reported meaningful training effects for other perceptual-cognitive skills (e.g., Hagemann et al., 2006). Moreover, and according to Goldstone's (1998) cognitively driven approach to perceptual learning, mere exposure to domain-relevant stimuli is sufficient for learning to occur. With individuals in the present study repeatedly exposed to patterns of play in soccer, the three experimental groups were expected to show pre to post training improvements for pattern-recognition skill relative to the control group. Findings from the present programme of work (see Chapters 2 and 3) as well as research by Williams et al. (2006) and North et al. (2009, 2011) have demonstrated the importance of relative motion information between the central attacking players when making accurate recognition judgments. It was therefore predicted that the visual and verbal guidance groups would demonstrate greater improvements in pattern-recognition skill than the video-only and control groups as these conditions oriented participants' attention to this information. Given the equivocal research findings concerning the efficacy of visual-guidance and verbal-instruction (Hagemann et al., 2006; Ryu et al., 2013; Abernethy et al., 2012), it was not possible to make exact predictions regarding which training method would be the most effective in training pattern-recognition skill.

As discussed previously, there are contrasting arguments concerning the relationship between pattern-recognition and anticipation skill (e.g., North et al., 2009, 2011; Ericsson & Lehmann, 1996). Nevertheless, and given the findings from the previous chapter concerning the potential importance of pattern-recognition when making anticipation judgments, as well as many researchers considering the knowledge of playing patterns to be crucial to expertise in team-ball sports (e.g., Abernethy et al., 2005; Williams & Davids, 1995; Williams et al., 2006), it was predicted that developing the ability to recognise sequences of play would lead to improvements in anticipation performance.

## Method

### Participants

A total of 64 participants volunteered to take part in the study. They were divided equally into four groups; control (*M* age = 19.5 years, *SD* = 2.07), visual attention-guided (*M* age = 20.2 years, *SD* = 3.24), verbal instruction-guided (*M* age = 19.8 years, *SD* = 3.67), and video-only (*M* age = 20.9 years, *SD* = 2.47). They were all amateur soccer players, having played at only recreational or school level, for an average of 9.24 years (*SD* = 2.55). Due to the nature of the test films, participants were checked for colour blindness (of which there were none), and reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of Liverpool John Moore’s University. Participants provided informed consent and were free to withdraw at any stage.

### Test Stimuli

For the recognition and anticipation test films as well as the perceptual training footage, stimuli were taken from matches involving the reserve or second teams of professional clubs and did not include any matches involving the participants or players with whom they were familiar. The sequences were filmed using a fixed, tripod-mounted video camera (Canon XM-2, Tokyo, Japan) in an elevated position (approximate height 9-metres) behind (approximate distance 15-metres) the goal. The camera did not pan or zoom during recorded. This camera position ensured that the entire field of play was visible and that information from wide areas of the field of play was not excluded. The action sequences were filmed from as close as possible to the central defender's position in the game, with all patterns of play emerging in the direction of the viewer. This viewing perspective has been shown to accurately capture expert performance (see Ripoll et al., 2005) and construct-validity has been established for the use of such clips in previously published reports (e.g., Williams et al., 2006; North et al., 2009; Ward & Williams, 2003). All sequences of play involved a number of passing manoeuvres mostly commencing in the defensive half of the pitch and ending with either; a penetrative pass to an advanced team-mate, a cross into the opposition's penalty box, or a shot on goal. To ensure only structured clips were used, three expert soccer coaches independently rated each sequence as high or low in structure using a Likert-type scale from 0 to 10 (0 being very low in structure, 10 being very high in structure). The clips deemed high in structure were those that were viewed by the coaches to be most representative of tactics, manoeuvres, and plans typically observed during offensive sequences of match-play. Only sequences with a mean rating of 7 or above were used in the test films and training footage.

**Recognition Stimuli**

Participants were presented with two separate test films. The first test film, representing the viewing phase, was comprised of 40 film clips, each of which was 7-seconds in length. The initial 2-seconds presented a freeze-frame of the action, as participants were cued to the location of the ball by a black circle before the onset of the clip. Following this 2-second freeze frame, 5-seconds of dynamic activity ensued as participants were shown a pattern of play, followed by an inter-trial interval of 3-seconds before the next clip commenced. The second test film was the recognition film which also included 40 film sequences, 20 of which were taken from the viewing phase, whilst 20 were new action sequences that had not been seen previously by the participants.

**Anticipation Stimuli**

The anticipation test film served as a pre and post-test measure to determine the efficacy of the perceptual training footage in developing anticipation. A 2-second freeze frame was employed prior to the onset of each clip, during which a red circle cued participants to ball location (see Figure 5.1). Each clip then showed 6-seconds of dynamic activity that began in the defensive half of the field and concluded in the attacking half, with the player in possession of the ball about to make a penetrative pass to another team-mate in a more advanced attacking position. Prior to the pass being executed, the final frame of the action sequence was paused for 2-seconds to allow for each player in a position to receive a pass to be highlighted by a coloured circle; red, blue, black and yellow (see Figure 5.2). Participants were then required to anticipate final pass destination by marking down the circle colour they thought corresponded to the player most likely to receive the pass.  After the 2-second freeze-frame, the clip occluded. In all, there were 24 trials, each of which lasted for 10-seconds with an inter-trial interval of 5-seconds.

Figure 5.1: An example freeze-frame prior to the onset of each clip with the starting position of the ball indicated with a red circle.

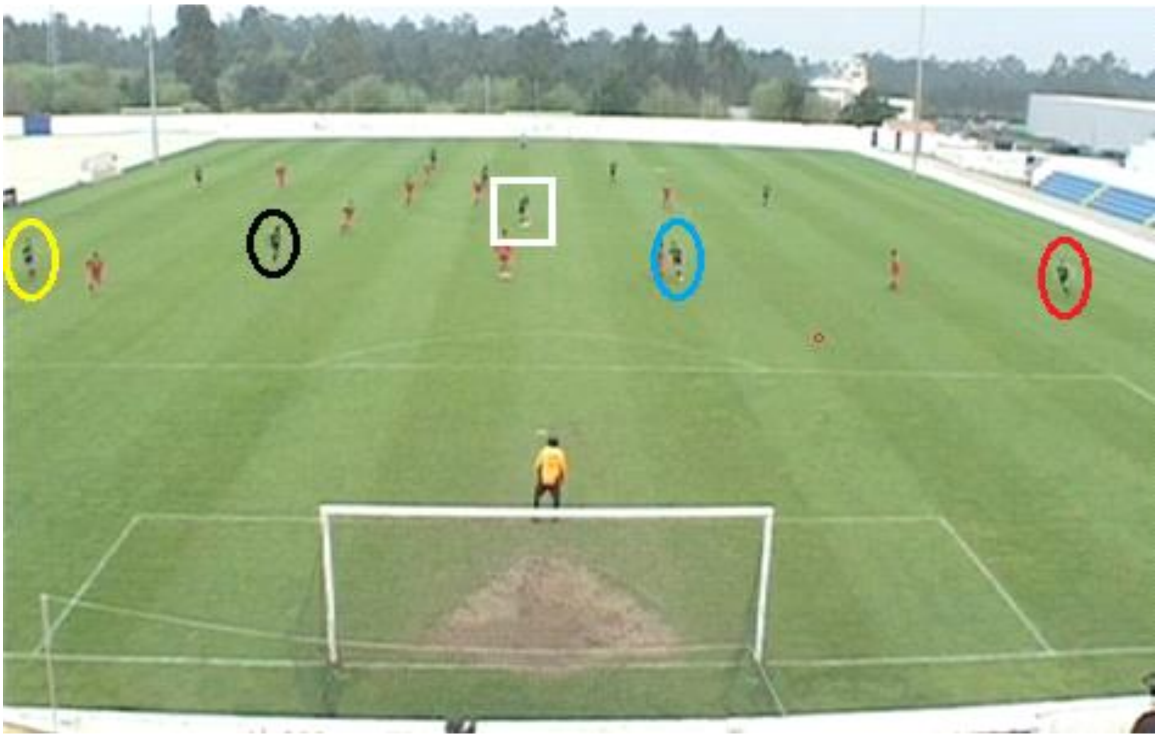

Figure 5.2: An example freeze-frame prior to the player in possession of the ball making a penetrative pass.

## Perceptual Training Stimuli

In total, there were 120-action sequences spread equally over 4 training sessions. The training itself comprised of 4 different test groups, the nature of which are described below:

*Verbal Instruction Group (explicit)* - At the onset of each clip, a freeze-frame of the action cued participants to ball location using a black circle. It also served to draw attention to the runs and movement between 'key' players within the video sequence. In line with Chapters 2 and 3 of the current programme of work as well as previous findings (e.g., Williams et al., 2006; North et al., 2009; 2011), participants were verbally instructed to focus their attention on the movement of the central offensive players as the pattern of play unfolded. In the main, these were the central forwards (e.g., *striker to the left of the ball as well as the more advanced striker to the left of the D*). In some clips however, the instructions given were specific to the particular action sequence. For example, the movement of the strikers would occasionally create space for another player to make a penetrative run into the opposition's final third, such as the winger or central midfielder. In these situations the pattern of play would often take time to evolve, as decisive player runs only materialised half way through the clip itself. Under these circumstances a freeze-frame would highlight the position of the ball as well as the movement of the central forwards at the start of the clip (e.g., *two strikers to the right side of the penalty area*). The sequence would then play as normal until another freeze-frame was inserted at an appropriate point to highlight a particular player's run into an attacking position (e.g., *right centre midfielder who just played the ball*). Once highlighted, the clip would play again until a pass, cross or shot was made. The action sequences showed 6-seconds of dynamic activity, although they were often longer depending on the amount of information that had to be conveyed to the learner (i.e. number of freeze-frames employed).

Verbal instructions were quite detailed as participants had to be directed to runs and movements of 'key players' (typically two or three out of a possible twenty-two on the field).

As a result, each training session depicted only one of the teams attacking which narrowed down the number of potential players they had to focus on. Certain landmarks of the pitch were also used to ensure the correct players were highlighted (e.g., *the striker in the centre circle as well as the far left striker on the halfway line*).

*Visual Guidance Group (guided-discovery)* - The action sequences employed in this group were the same as those used in the verbal instruction group. A 2-second freeze-frame of the action was presented to the viewer and a black circle identified ball location prior to the onset of the clip. This time however, 'key' players were highlighted by means of visual guidance cues. This was achieved by surrounding the relevant players with a red circle and an adjoining arrow to highlight their movement within the pattern of play (see Figures 5.3 and 5.4). All visual cues were presented during the freeze-frames of action, as it was felt that cues during dynamic activity would potentially obstruct the runs and movements of the players and thus prove to be a distracting source of information. As a measure to ensure that the same amount of guidance was given to each experimental group, the exact same players were highlighted, whilst the length of each freeze-frame was also matched between the two guidance groups.

*Video-Only Group (discovery)* - Participants in this group viewed the same perceptual training clips as those presented in the verbal instruction and visual guidance groups, which included the initial 2-second freeze-frame highlighting ball location at the start of each action sequence. Participants received no information regarding where they should look and which players to focus on.

*Control Group* – Participants in this group did not receive any training, and were simply required to complete the pre and post recognition and anticipation paradigms.

Figure 5.3: An example freeze-frame highlighting ball location and the position and subsequent movement of the two central forward players.

Figure 5.4: An example freeze-frame highlighting ball location and the position and subsequent movement of the central forward and central midfielder.

## Apparatus

For the three separate phases of the study, the apparatus remained the same. Film clips were presented using a DVD player (Panasonic, DMR-E50, Osaka, Japan) and projector (Sharp, XG-NV2E, Manchester, UK) with images being presented onto a 9' x 12' screen (Cinefold, Spiceland, IN, USA) at a rate of 25 frames per second with XGA resolution. Verbal instructions were recorded onto a Dictaphone and transferred onto the test films using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA); which was also used to create the test films and freeze frames of action. The highlighting of ball location (at the onset of each clip) and attacking players (in the visual guidance group and anticipation test) was achieved with the 'Microsoft Paint Program' (Microsoft Corporation, 2010).

## Procedure

Participants underwent each aspect of the perceptual training programme individually, sat in a chair at a distance of 3-metres from the screen such that the image subtended a visual angle of approximately 40-degrees. The entire programme was spread over a 2-week period, meaning there were approximately 2.5 days between each training session and the respective testing phases.

*Pre-test* - Participants were briefed as to the general training procedure before undertaking the pre-test recognition paradigm, which took approximately 20-minutes to complete. They then had a 10-minute break during which time they filled-out a questionnaire to examine their playing history within the sport of soccer. Participants then underwent the pre-training anticipation test, which lasted for approximately 10-minutes.

*Perceptual training* - From their pre-test recognition scores, participants were assigned to four equally matched-ability groups: visual guidance; verbal instruction; video-only; and control group. In all there were four training sessions, each of which included 30-action sequences with an inter-trial interval of 5-seconds, and took around 20-minutes to complete. No responses were required from the participants during the training sessions; they were informed to simply watch the clips and pay attention to any cues within the action sequences.

*Post-test* - Two days after the final training session, each experimental group undertook the post-test phase of the study. In an exact replica of the pre-test, participants completed the recognition and anticipation tests respectively. In an attempt to prevent familiarity bias and expectancy effects, the order of clip presentation was randomised for both paradigms, whilst the clips that were repeated in the pre-test recognition paradigm were also changed.

**Procedure for Test Stimuli**

*Recognition Paradigm* – During the viewing phase, participants were informed that they would be presented with a series of film clips from soccer matches showing sequences of play, with a black circle highlighting ball location at the beginning of each. Participants were informed that each clip would show an attacking pattern of play leading to a pass into an offensive area, although the action would be occluded at the final moment before this event occurred. Participants were instructed to watch the clips as if playing in the match, adopting the perspective of a central defender. No response was required during this phase of the paradigm. After presentation of the viewing film, there was a 10-minute comfort break. Participants were then asked to view a second series of clips, some of which what been presented previously in the viewing film and others that were novel. Participants were instructed to watch each action sequence for its entire duration and make a recognition decision as to whether or not it had been presented in the earlier viewing phase, with a "yes" or "no" pen and paper response sheet. After each action sequence, the video image was occluded immediately with a 2-second '*Respond Now*' freeze-frame.

*Anticipation Test* - Participants were informed that they would be presented with a series of soccer clips showing attacking patterns of play, with a red circle highlighting ball location at the beginning of each clip. Players were asked to watch these clips as if playing in the game itself, adopting the perspective of a central defender. They were instructed that each action sequence would pause just before the player in possession of the ball made a penetrative pass to another team-mate in a more advanced attacking position. At this moment, participants were asked to anticipate final pass destination by choosing the coloured circle that corresponded to the player they thought most likely to receive the ball, using a pen and response sheet. After the freeze-frame, the video image was occluded immediately with a 2-second '*Respond Now*' clip.

**Data Analysis**

*Recognition Performance*

Signal detection measures of sensitivity (*d*) and response bias (c) were used to measure recognition accuracy (Green & Swets, 1966). The data for *d* and *c* were analysed separately using a mixed design 2-way analysis of variance (ANOVA) in which the between-participants factor was Group (control/visual/verbal/video) and the within-participants factor was Training (pre vs. post).

*Anticipation Performance*

Anticipation accuracy was obtained by dividing the number of correct responses by the total number of trials ($n$ = 24) and multiplying by 100 to create a percentage accuracy score. Responses were marked as correct or incorrect based upon whether participants highlighted the actual player who received the ball out of the 4 available passing options. These data were analysed using a mixed design 2-way analysis of variance (ANOVA) in which the between-participants factor was Group (control/visual/verbal/video) and the within-participants factor Training (pre vs. post).

Prior to running each analysis, the data were tested for normality using a Shapiro-Wilks test. Partial eta squared ($_{p}^{2}$) values are provided as a measure of effect size for all main effects and interactions and, where appropriate, Cohen's *d* measures are reported for comparisons between two means. For repeated measures ANOVAs, violations of sphericity were corrected by adjusting the degrees of freedom using the Greenhouse Geisser correction when the sphericity estimate was less than 0.75, and the Huynh-Feldt correction when greater than 0.75 (Girden, 1992). The alpha level for significance was set at $p$ <.05.

## Results

### *Recognition Performance*

Analysis of *d*' revealed a significant main effect for Training, $F_{1, 60}$ = 16.532, $p$ <.01, $_{p}^{2}$ = .216. Participants were significantly more sensitive in their recognition decisions at post-test ($M$ = 0.55 $SD$ = 0.5) compared to pre-test ($M$ = 0.37, $SD$ = 0.52), $d$ = 0.34. However, the Group x Training interaction, $F_{3, 60}$ = 1.534, $p$ > .05, $_{p}^{2}$ = .071, and the main effect for Group, $F_{3, 60}$ = .488, $p$ > .05, $_{p}^{2}$ = .024, were not significant.

The analysis of *c* showed no main effect for Training, $F_{1, 60}$ = .394, $p$ >.05, $_{p}^{2}$ = .007, or Group, $F_{3, 60}$ = .310, $p$ > .05, $_{p}^{2}$ = .015. Similarly, the Group x Training interaction was not significant, $F_{3, 60}$ = 1.413, $p$ >.05, $_{p}^{2}$ = .066. In summary, these data demonstrate that there was no differential bias between groups for a tendency to respond 'yes' or 'no' when making their recognition decisions.

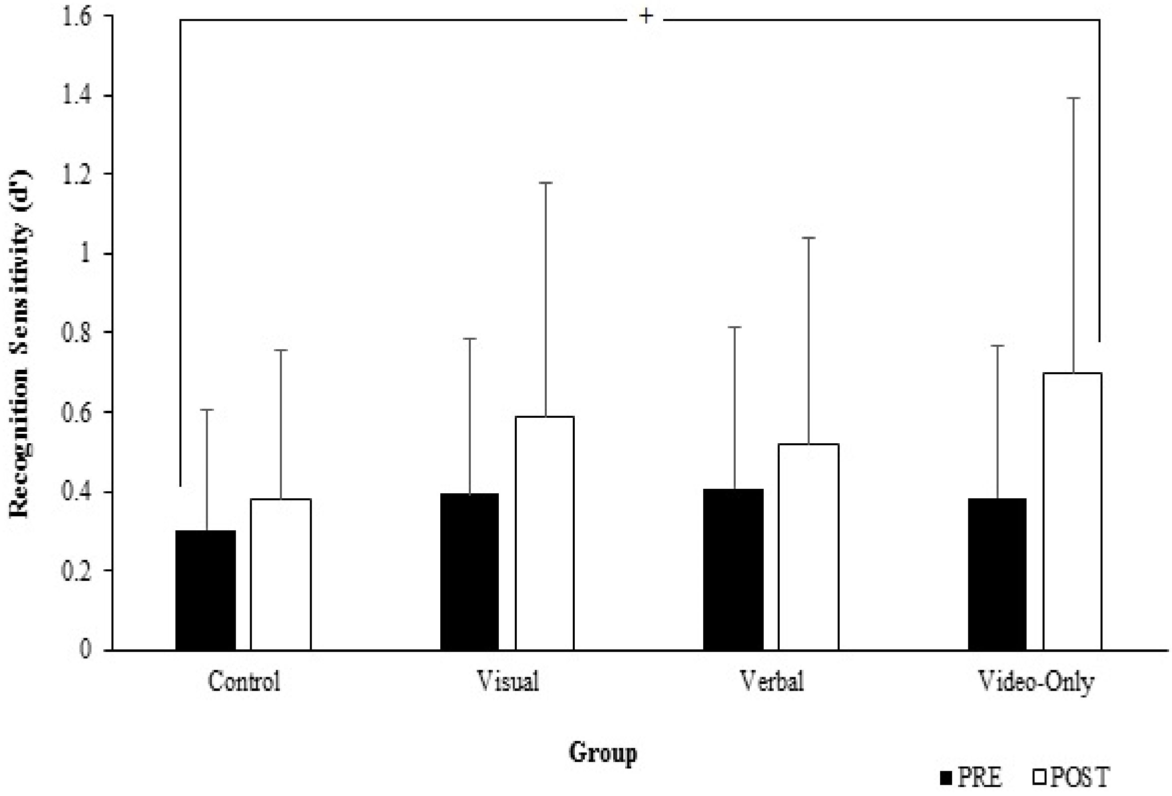


Figure 5.5: Mean recognition sensitivity (with SD bars) in the pre-test and post-test for control and training groups. + Significant differences in scores collapsed across experimental condition for training.

*Anticipation Performance*

ANOVA revealed no main effect for Training, $F_{1, 60} = 3.613$, $p > .05$, ${}_{p}^{2} = .057$, or Group, $F_{3, 60} = .216$, $p > .05$, ${}_{p}^{2} = .011$. The Group x Training interaction was also not significant, $F_{3, 60} = .407$, $p > .05$, ${}_{p}^{2} = .0.20$.

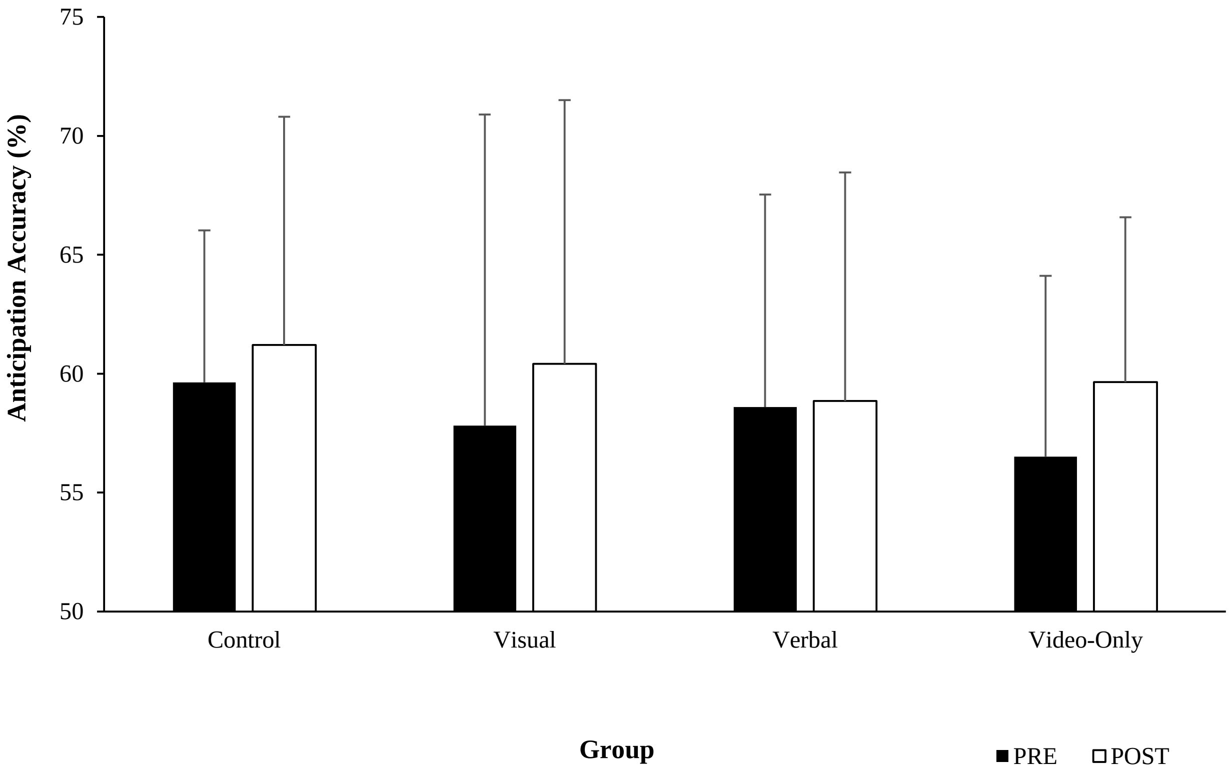


Figure 5.6: Mean anticipation accuracy (with *SD* bars) in the pre-test and post-test for control and training groups.

## Discussion

The primary intention of this study was to determine whether pattern-recognition skill could be trained in the game of soccer. The efficacy of various different instructional approaches in directing the learner's attention to key perceptual cues within the visual display was also compared. A final aim was to investigate whether any training effects for pattern-recognition transferred to observed improvements in anticipation.

With regards to recognition performance as a function of group, it was predicted that with repeated exposure to task-relevant stimuli, individuals who underwent the intervention would improve their pattern-recognition (Goldstone, 1998). Initial findings supported this hypothesis as participants' were significantly more sensitive in their recognition decisions at post-test compared to pre-test. It was further envisaged that the guidance groups (visual and verbal) would demonstrate the greatest improvements in recognition performance when compared to the video-only (discovery) and control groups. The data failed to support this prediction, with no main effect for Group or Group x Training interaction observed. These null findings subsequently confound the earlier training effect with the observed improvements in recognition accuracy most likely to be a result of increased test familiarity and/or confirmation bias. It should be noted that there were some very slight trends observed in the data, as the visual-guidance group demonstrated the most improvement from pre to post-test (+ 4.7 %), whereas the verbally-instructed group actually revealed a slight decrement in recognition performance (- 0.94 %). Given the paucity of literature concerning the optimal frequency and scheduling of perceptual training sessions (Williams & Grant, 1999) these tendencies may have become more pronounced with an increased training load. To this end, Ryu and colleagues (2013) reported positive training effects for colour cueing in novice goalkeepers, but participants in their study observed 384 training trials before the benefits of guidance supplementation began to emerge. In contrast, participants in the current training programme were subjected to less than a third of that (120 trials). Thus, and while the data provide tentative support for the potential efficacy of colour cueing (e.g., Hagemann et al., 2006), the null findings for Group and Group x Training posit that no meaningful conclusions can be drawn from the study.

From a theoretical perspective, Goldstone's (1998) cognitively driven approach to perceptual learning was used as a rationale for the envisaged training effects. Although none of any significance were observed, the theory may also be used to speculate as to reasons why. The first step of his paradigm emphasises the importance of attentional weighting to perceptual learning, where a distinction is made between relevant and irrelevant stimuli within the visual display. In order to facilitate this mechanism in the current study, individuals were given either verbal instruction or colour cueing as to the important perceptual features on which to focus their attention on (i.e., the relative motion between the central offensive players). The second mechanism refers to imprinting, where it was envisaged that the participants in the guidance groups would develop specialised receptors for these players over the course of the training intervention, in order to increase the accuracy and general fluency with which these key features were processed. Topological imprinting is also a crucial component of this stage, as the space and positions of patterns within a specific area are learned. Clearly, this is an extremely important process for developing pattern-recognition skill in soccer. As previously alluded to, the number of training clips within the intervention may have impacted significantly on this stage, given the specialised receptors may not have developed sufficiently to pick up the relative movement between the central offensive players. To this end, differentiation would have also been inhibited. That is, the process of discriminating between stimuli that were previously indistinguishable, to facilitate discrepancy between component parts. The current training intervention was explicitly designed to develop amateur player's ability to pick up the relative motion of the central offensive players within the global structure, and thereby improve their pattern-recognition skill. While only speculation, it is plausible that the limited number of training clips impeded this process (in conjunction with imprinting), and therefore accounted for the null effects reported.

With regards to the verbal-guidance group, another possible explanation for the non-significant effects pertains to the way in which the information was conveyed to the learner. When training individuals under conditions of high uncertainty, both Kirlik et al. (Kirlik, Walker, Fisk, & Nagel, 1996) and Magill (1998) have questioned the effectiveness of explicit instruction methods. As previously alluded to, this genre of instructional design is proposed to result in the development of consciously controlled declarative knowledge, which becomes proceduralised over time (Anderson, 1982). Although knowledge stored in 'if-then' statements may suffice for straight-forward decisions, less prescriptive types of instruction may be more beneficial when training anticipation for the unpredictable nature of sport. Given its dynamic nature, the game of soccer can be considered a particularly uncertain domain, with the constant interaction between the players and ball. In order to ensure the participants in the verbally-guided group focussed on the correct players in the training clips (2 or 3 out of a possible 22 on the pitch), they were given fairly detailed instructions. Thus, it could be argued that the null effects reported for the verbal-guidance group are hardly surprising, given the overall level of uncertainty within the stimuli and the explicit nature of instructional design employed to direct the learners' attention to key perceptual features (Kirlik et al., 1996; Magill, 1998).

This rationale would fit with Sweller's (1988) cognitive load theory (CLT), which accounts for why individuals have difficulty in learning cognitively complex or technically challenging material. Incorporating facets from Miller's (1956) information processing theory and the concept of 'chunking', whereby short-term memory can only hold 5-9 chunks of information (seven plus or minus two), CLT highlights the inherent limitations of concurrent working memory load on learning. The theory is therefore concerned with the instructional techniques for managing working memory load in order to facilitate changes in long-term memory associated with schema construction and automation (i.e. learning). Although one can only speculate as to why null findings were observed in the present study, it is plausible that the explicit instructions imposed too much extraneous cognitive load on the participant's working memory, given their amateur skill level and insufficient schema construction to deal with the presented stimuli. As a result, germane cognitive load would have been inhibited, thereby hampering learning.

When faced with challenging material, Magill (1998) suggests that implicit instructional techniques may be more effective than explicit awareness strategies. In keeping with Sweller (1988), this may also reduce cognitive load in order facilitate schema construction and learning. Colour cueing was therefore used as a means of guided-discovery in the visual group in order to draw the learner's attention to the relative motion information between the central forward players. Although the descriptive data hinted towards better performance in this training group, findings were not significant. In order to account for the reported data (and other than the potential effects of training load), it is conceivable that the instructional methods employed in the visual-guidance group were overly descriptive in nature, given the learner's attention was orientated more towards the positional location of 2/3 key players within the pattern of play rather than highlighting the relative motion information between these players (see North & Williams, 2007). According to Magill (1998), implicit processing is induced by orientating attention toward information rich areas that contain the most important motion features, as oppose to specific perceptual cues. In addition, the freeze-frames employed to emphasise crucial movement patterns for both guidance groups, may have actually disrupted motion information, and thus impeded efforts to train pattern-recognition skill (Williams et al., 2012).

These observations fit nicely with the work on breadth of attentional focus, which is considered crucial for the processing of visual information (Castiello & Umilta, 1990; Eriksen & St. James, 1986; Eriksen & Yeh, 1985). Researchers have demonstrated how breadth should vary to accommodate the genre of sport (Nougier, Stein, & Bonnel, 1991). For example, in sports with an invariant visual setting (e.g., archery) a narrow focus is advantageous. However, in a continuously changing environment typically observed in open-skill sports, a relatively broad focus oriented toward the centre of the relevant information is preferable (Ripoll, 1988). Although the highlighting of relative motion information between the central offensive players served as an empirical basis on which to design the perceptual training programme, it is plausible that the breadth of attentional focus (for both guidance groups) may have been too narrow for the amateur level players in the present study (see Abernethy, 2001). To this end, researchers have demonstrated how players develop an appropriate breadth of attentional focus with increasing experience, making it one of the features of expertise in a particular sport (Nougier et al., 1991). For this reason, a wide breadth of attention has been advocated when delivering instruction to beginners (Abernethy, 2001; Memmert, 2006), with some researchers suggesting that simulation training may be more effective with intermediate and advanced level learners rather than novices (Alessi, 1998; Andrews, 1988; Lintern, Shepard, Parker, Yates, & Nolan, 1989).

In support of a wide breadth of attentional focus, Memmert and Furley (2007) examined the effects of instruction design on a tactical decision-making task in handball. Their findings revealed participants who received explicit tactical instructions (attention-narrowing) demonstrated inferior decision-making when compared to those given no instructions (attention-broadening). It was subsequently concluded that players in team-based sports need a wide breadth of attention in order to generate tactical response patterns and seek original solutions in their game plans (Memmert & Furley, 2007). In view of these findings, as well as the aforementioned process of stimulus imprinting within the perceptual learning literature (Goldstone, 1998), the video-only group in the present study were expected to demonstrate meaningful training effects given their repeated exposure to domain-relevant stimuli. The data however failed to support this hypothesis, with no discernible change in recognition performance reported over the training intervention. Again, this could be attributed to the limited number of training clips, but equally, findings for discovery learning groups in other training programmes have also proved equivocal. To this end, some racquet-based studies have reported positive training effects in tennis (Smeeton et al., 2005) and badminton (Hagemann et al., 2006) respectively, while more recent penalty-based soccer paradigms have failed to attain any significant improvements when compared to a control group (e.g., Ryu et al., 2013; Savelsbergh et al., 2010). Although methodological design varies considerably between all of these studies, it seems further research is needed to examine the efficacy of discovery learning in perceptual training programmes.

With recent literature providing evidence for an anticipatory encoding process in the sporting domain (Didierjean & Marmèche, 2005; Gorman et al., 2011, 2012, 2013b), as well as many researchers considering the knowledge of playing patterns to be a strong predictor of anticipation in team-ball sports (e.g., Williams & Davids, 1995), a secondary aim of the present study was to examine whether potential training effects for pattern-recognition transferred to anticipation. Contrary to original predictions, findings revealed no main effects for Group and Training, and no Group x Training interaction. Given the null findings reported for recognition performance, it could be argued that the data for anticipation accuracy is hardly surprising. Nevertheless, it remains unclear whether the training protocol itself was the cause of such results, and/or if perceptual skills other than pattern-recognition are more pivotal in guiding anticipatory judgments.

Williams and Ward (2007) suggest perceptual-cognitive skills are not mutually exclusive and interact with each other in a dynamic manner during performance. In support of this, Newell (1986) proposed their relative importance will vary as a function of the task, situation and performer. The previous chapter explicitly examined the effect of task constraints on anticipation and provided evidence to suggest that skilled players rely mainly on pattern-recognition skill when viewing the action from afar, and postural cue information of the player in possession of the ball when the passage of play becomes more localised and time-constrained (see also; Roca et al., 2013; Vaeyens et al., 2007a, b; Williams & Davids, 1998). These findings may help to explain the null effects reported in the current study given the anticipation test clips all occluded in the attacking half of the pitch just before a penetrative pass was made.

Under these ‘micro-states’ of the game (i.e., 3 vs. 3, 3 vs. 1 or 2 vs. 1 situations) the abovementioned research (see Vaeyens et al., 2007a, b; Williams & Davids, 1998) has demonstrated how situational probabilities (Ward & Williams, 2003) and advance cue utilisation (e.g., Williams & Davids, 1998) become more pivotal in guiding anticipatory judgments. The training intervention however, was designed to improve pattern-recognition skill from a more open, whole-sided perspective (i.e., 11 vs. 11 situations; see Roca et al. 2013), hence why the relative motion information between the central offensive players was highlighted, and not the postural cues of the player in possession of the ball. For this reason, the design of the protocol itself may have been partly responsible for the null effects reported. These observations also serve to highlight the relative interaction between the different perceptual-cognitive skills during performance (e.g., Roca et al., 2013; Newell, 1986), meaning pattern-recognition may not always be fundamental to anticipation performance in certain situations (Williams & Ward, 2007).

In view of this, North and colleagues (2009; 2011) further explored the processes underpinning stimulus recognition and anticipation in soccer. Expert-novice anticipation and recognition paradigms were undertaken while eye-movement data and verbal protocol analysis were collected. In keeping with extant literature, expertise effects were found for pattern-recognition and anticipation, yet no significant correlations were found between the two constructs for skilled or less-skilled players. This was supported by the complementary process tracing measures, which provided evidence to suggest that whilst recognition and anticipation share similar properties, their specific processing strategies differ somewhat. Specifically, when asked to anticipate as oppose to recognise sequences of play, skilled players fixated on more locations, showed an increase in the number of fixations, and recorded shorter fixation durations. For the verbal protocol analysis, they verbalised more stimuli, actions, and cognitions. Taken together, these process tracing measures infer that anticipation is more complex, invoking different and more refined retrieval structures. To this end, and while the literature on pattern perception (Didierjean & Marmèche, 2005; Gorman et al., 2011, 2012, 2013b) as well as findings from the previous chapter, suggest that skilled players are able to use pattern-recognition skill to facilitate anticipation judgments, the extent to which these two constructs are directly related remains unclear, given the null effects reported in the present study.

In conclusion, findings from the previous chapters of work relating to the nature of information underpinning skilled familiarity perception of dynamic soccer action sequences provided a principled basis for the training intervention employed in the current study. Despite a main effect for Training, the data failed to yield any significant interaction for Group pertaining to the most effective instructional method for enhancing pattern-recognition skill in soccer. Similarly, no meaningful training effects were obtained for anticipation. As discussed, there are many potential reasons for the observed null findings, such as the way in which the information was conveyed to the learner (Magill, 1998), and the relative importance of other perceptual-cognitive skills to anticipation performance (Newell, 1986). It therefore remains to be seen whether pattern-recognition skill can be improved through perceptual training programmes alone, or if physical practice is an essential prerequisite when developing this skill. Clearly further research is required in this area, especially given the potential value of such interventions if proven successful in enhancing pattern-recognition skill.

# Chapter 6: Epilogue

This chapter will provide a detailed synthesis of the work presented in the thesis and outline implications to both theory and practice. Limitations of the studies will be discussed, as well as potential avenues for future research in the area.

### Aims of the thesis

The overall aim of the thesis was to extend previous literature on perceptual-cognitive expertise by identifying the nature of information underpinning skilled familiarity perception, and whether this could subsequently be used to train pattern-recognition skill and potentially anticipation in soccer. In Chapter 2, three experiments are presented to identify the specific information sources that skilled participants use to make recognition judgments when presented with dynamic, structured stimuli. Although initial reports suggest that skilled performers perceive and process displays involving numerous elements as relational information (North et al., 2009; Williams et al., 2006), it has yet to be determined whether this relational information is picked up from positional or motion information. Using the recognition paradigm, a technique that is reported to measure an important component of anticipation (Abernethy et al., 2005; Williams & Davids, 1995), Experiments 1 and 2 attempted to manipulate motion information within the presented stimuli to gain a better understanding of the nature of information underpinning skilled recognition. Experiment 3 explored whether relationships between certain display features are more important than others when making familiarity judgments. With a greater appreciation for the nature of information underpinning skilled recognition in structured soccer displays, Chapter 3 examined whether familiarity could still be perceived when only the minimal essential information was presented.

Although researchers propose that the ability to recognise familiarity may be an important precursor to high-level performance in soccer (e.g., Cañal-Bruland & Williams, 2010; Chabris & Hearst, 2003; North et al., 2009), anticipation in dynamic team games has been shown to be dependent on a range of perceptual-cognitive skills (e.g., Williams & Ward, 2007). With the exception of Roca et al. (2013), there have been very few reported attempts to examine how these skills interact with each other in a dynamic and evolving manner to facilitate anticipation performance. With notable methodological amendments, Chapter 4 developed the tenets from the aforementioned research to further explore the relative importance of pattern-recognition and postural cue usage to anticipation judgments as a function of the unique task constraints.

Lastly, Chapter 5 incorporated findings from earlier studies (see Chapters 2, 3, and 4), to design and implement a perceptual training programme to try and improve familiarity-based judgments in a group of amateur level soccer players. An additional aim was to compare the effectiveness of various perceptual training techniques in developing pattern-recognition skill. A final goal was to examine whether potential training effects for pattern-recognition transferred to anticipation performance, given that their relationship remains a contentious issue within the expertise literature (e.g., Williams & Davids, 1995; Ericsson & Lehmann, 1996).

**Summary of Key Findings**

As detailed in Chapter 2, three experiments were undertaken in an attempt to identify the specific information sources that skilled participants use to make recognition judgments when presented with a series of stimuli sampled from 11 vs. 11 soccer matches. In all experiments, an incidental recognition paradigm was employed in which skilled and less skilled players were initially shown dynamic film footage occluded at the final frame prior to an attacking pass being made. In a subsequent recognition phase, participants were presented with new and previously seen stimuli and were required to make judgements as to whether or not each sequence had been presented earlier (or were edited versions of earlier sequences). The sensitivity of participants' recognition judgments and their response bias were taken as measures of performance.

In Experiment 1, the ability of participants to perceive familiarity in the display through reference to the locations of display features or via reference to the motions of these features (i.e., the players and/or the ball) was examined. In the recognition phase, action sequences were edited to manipulate access to motion information by creating three different clip types: dynamic, static images, and footage where the individual frames of the film sequence were presented randomly in a non-sequential order. Skilled participants demonstrated superior recognition sensitivity when viewing dynamic clips, compared with static images, and the randomised format, respectively. In contrast, the less skilled participants did not differ in recognition sensitivity across the three viewing conditions. These findings were taken as evidence of the importance of motion information when identifying familiar and unfamiliar action sequences.

Experiment 2 examined whether participants perceive familiarity by picking up absolute motion information from one or more display features, or by perceiving relative motions between features. The recognition phase presented participants with both normal and mirror-reversed action sequences in order to distort access to absolute motion information, whereas the relative motion between features remained constant. Skilled participants demonstrated superior recognition sensitivity over their less skilled counterparts, but no significant differences were observed across viewing conditions, providing evidence to suggest that skilled participants are more likely to extract relative rather than absolute motion between features when making recognition judgements.

In Experiment 3, an attempt was made to better identify the specific relative motion information that skilled participants extract from the display when making familiarity-based judgments. In order to ascertain the key features, or combination of features, localised relative motions between features were manipulated by occluding several display features for the duration of each film sequence, in an attempt to evaluate their impact on subsequent recognition sensitivity. In the control condition (Condition 1), four players from peripheral positions were occluded. In another condition (Condition 2), the two central offensive players and their corresponding defensive markers were occluded, while in another condition (Condition 3) two central midfield players as well as their defensive markers were occluded. In a final condition (Condition 4), one central offensive player and one central midfield player were occluded as well as their corresponding markers. The data provided evidence to suggest that the relative motions between only a few key features are crucial, notably the relationships between the central offensive and central midfield players. In contrast, relative motions between pairs of offensive or midfield players as well as other more peripheral features appear to be less important for skilled participants to perceive meaning and structure to inform their recognition decisions.

In an attempt to validate these findings, Chapter 3 further examined the importance of relative motion information between central offensive features when making recognition judgments to soccer action sequences. A somewhat exploratory spatial occlusion approach was employed which acted to remove most of the perceptual stimuli available to the performer during scene recognition (as oppose to relative motions between just two key features), to determine whether participants could perceive global structure on the basis of micro patterns between a limited number of display features. Moreover, action sequences were presented in point-light display (PLD), to further explore the importance of relative motion information when perceiving familiarity in dynamic, interactive stimuli. An incidental recognition paradigm was again employed with skilled and less skilled participants initially presented with structured action sequences, showing dynamic footage occluded at the final frame prior to an attacking pass being made. In a subsequent recognition phase, clips were selectively edited to occlude a number of features and create three experimental conditions; Condition 1 showed only two peripheral players, Condition 2 presented the two central offensive players, and Condition 3 showed two central offensive players as well as the player in possession of the ball. Findings demonstrated how there was no difference in recognition accuracy between skilled and less-skilled participants when just peripheral players were presented. In contrast, when presented with the relative motions of the two central offensive players, skilled participants were significantly more accurate at detecting familiarity than their less skilled counterparts. This skill advantage was increased further when a ball (target feature) was included against which these relative motions could be judged against. The Skill x Display interaction provided evidence to suggest that skilled players perceive and recognise global patterns on the basis of localised information sources. Specifically, the relative motions between central offensive players represents the minimal essential information required to recognise patterns in dynamic soccer action sequences.

The primary aim of Chapter 4 was to examine whether anticipation is underpinned by the perception of inter-individual (between participants; pattern-recognition) or intra-individual (within participant; postural cues) relational information. A secondary goal was to explore the effect of situational task constraints by manipulating the distance between the ball and the participants. An anticipation paradigm was employed presenting skilled and less skilled participants with a series of structured, offensive patterns of play from both a near and far viewing perspective. Action sequences were presented in either video or PLD to try and control for the amount of information presented in each format. Specifically, participants only had access to inter-individual relations between the multiple display features in the PLD condition (i.e. pattern -recognition), whereas the video condition showed this information as well as intra-individual postural cues and orientations of players. Skilled participants demonstrated superior anticipation performance regardless of display condition, providing evidence to suggest that both pattern-recognition and postural cue usage contribute to expert performance. Nonetheless, the Skill x Display interaction revealed that the skill advantage was exaggerated in the video condition, inferring that skilled players make better use of postural cues when available during anticipation. With regards to the impact of situational task constraints task on performance, when the participants were closer to the ball (near task), anticipation was more accurate for the video than PLD clips. In contrast, there was no difference between viewing conditions when the ball was further away (far task). Evidence was therefore provided to suggest that postural cue information is the primary perceptual-cognitive skill facilitating anticipation when the ball is in close proximity to the observer, whereas the two sources of information appear not differ in importance when the ball is further away.

With Chapters 2 and 3 exploring the nature of information underpinning skilled familiarity perception in soccer, Chapter 5 examined whether this information could be implemented into a perceptual training programme to improve pattern-recognition skill in a group of amateur level soccer players. An additional aim was to compare the effectiveness of various training techniques in highlighting key perceptual information to the learner, based on previous perceptual training literature (e.g., Jackson & Farrow, 2005; Hagemann et al., 2006). In view of Chapter 4 and the potential importance of pattern-recognition to anticipation, a final aim was to examine whether training effects transferred between the two constructs, to gain a better understanding of their potential relationship. Participants completed a pre-training recognition paradigm before being divided into four ability-matched experimental groups and undertaking the pre-training anticipation paradigm. Over a 14-day period, and with the exception of the control group who received no training at all, the three other experimental groups were given either verbal-instruction or visual-guidance cues as to the specific perceptual stimuli to focus on (i.e. relative motion between key features), whilst the video-only group watched the action sequences with no directive cues. All four experimental groups then completed the post-training recognition and anticipation tests. Although participants were significantly more sensitive in their recognition decisions at post-test compared to pre-test, findings were confounded by the lack of Group x Training interaction, with no main effect for Group reported either. Similarly, the anticipation data revealed no main effects for Group and Training, and no Group x Training interaction. The observed null effects for recognition performance provided no empirical support for the practical utility of training interventions designed to improve this particular perceptual-cognitive skill in soccer. Moreover, the data was unable to provide any additional evidence to suggest pattern-recognition is an important precursor to anticipation in team-ball games (e.g., Abernethy et al., 2005; Williams & Davids, 1995).

### Implications for Theory and Practice

The ability to recognise visual stimuli to perceive the intention of others is imperative to the successful completion of everyday tasks, from driving a car (McKenna & Horswill, 1999) to simply crossing the road (Carsten et al., 1989). The capacity to selectively attend to only the most relevant environmental cues while disregarding extraneous information becomes particularly important under temporal constraints, and is therefore a significant precursor to expert performance in many fields, such as military combat (e.g., Williams et al., 2008) and medical emergencies (e.g., Guise, 2007). It has been proposed that one of the perceptual-cognitive skills underlying the expert advantage in such domains is the ability to identify task-specific structure or patterns within the perceptual stimuli (e.g., Simon & Chase, 1973). For example, in anagram problem-solving tasks, Novick and Sherman (2003) argue that experts attend preferentially to underlying solution-relevant structural features (e.g., relations among objects), whereas novices tend to rely on solution-irrelevant superficial features of problems (e.g., the specific objects in the problem). Gentner and Markman (1997) propose that skilled performers are likely to perceive scenes based upon structural relations (e.g., positions of features or their relative orientations) and the higher order predicates they convey (e.g., tactical and/or strategic significance). In contrast, less-skilled performers rely upon lower level, superficial features such as the location of an isolated feature, or other potentially distinctive items, such as a body movement or environmental condition.

The proficiency of experts to identify task-specific structure or meaningful patterns from their domains of expertise, has typically been examined using the point-light technique. Using this approach, reflective markers are attached to the joint centres of an individual, with performance then filmed against a black background to remove all contextual information so that only the markers are visible, to ensure biological motion is presented in its simplest terms (Cutting and Profitt, 1982). From the remaining relational information between anatomical landmarks, research has shown how individuals are able to recognise familiar facial features or gait pattern of a friend (Barclay, Cutting, & Kozlowski, 1998; Peterson & Rhodes, 2003), and the mass of an object lifted by an individual (Shim et al., 2004). The point-light technique has also proved useful to examine the ability of experts to identify structure across display features in team-based sports. For example, Williams et al. (2006) demonstrated significant skill-based differences for the recognition of soccer action sequences presented in PLD, concluding that the positions of players on the field of play and the relational information between these, provides the necessary information for skilled participants to make successful recognition judgments.

Many researchers believe early recognition of familiarity in an evolving action sequence provides a significant advantage over an opponent, and is therefore a strong predictor of anticipation (e.g., Cañal-Bruland & Williams, 2010; Chabris & Hearst, 2003; North et al., 2009; Williams & David, 1995). Yet, only a few published reports outline the mechanisms underlying skilled perception or the specific information that performers pick up when making recognition judgments to dynamic, interactive, stimuli. Ensuing research using a variety of techniques and process tracing measures has provided evidence to suggest that skilled performers encode displays involving numerous features as a series of relationships arising in the final few moments preceding a critical event (e.g., Williams et al. 2006; North & Williams, 2007; North et al. 2009; 2011). Critically, however, it remained unclear as to whether these relationships are encoded as a function of specific features such as the locations or positions of isolated or superficial display features, or whether it is the relative or absolute motions between features that are essential when making such familiarity-based judgements. Through direct manipulation of motion information in the presented stimuli, Chapter 2 provided evidence to suggest that skilled performers perceive relational information as a function of relative motion between display features when attempting to detect familiarity within dynamic action sequences. Although researchers have demonstrated the importance of picking up intra-limb relative motion when anticipating opponents in closed skill situations, such as the return of serve in tennis (e.g., Abernethy et al., 2001), data from the present thesis implies that skilled performers are able to extract inter-individual relative motion between display features to facilitate familiarity judgments in more open, team-based sports.

At a conceptual level, these findings lend support to Dittrich's (1999) Interactive Encoding Model, which purports that when attempting to recognise familiarity within dynamic, interactive stimuli, skilled performers rely upon the relational information between features. In view of the work undertaken in Chapters 2 and 3, it would appear that this relational information pertains to the relative motions between key features (i.e. central offensive players and/or the player in possession of the ball) and the associated higher order strategic information conveyed by these relations (Gentner & Markman, 1997). The extraction of this information satisfies the initial low-level stage of processing outlined in the model, with skilled performers then engaging in a top-down matching process, where the relative motion information between features is matched against a high-level internal template/cognitive representation that has developed as a consequence of extended experience within the domain (e.g., Ford et al., 2009; Ward et al., 2007). In contrast, and with fewer practice hours, less skilled players are unable to develop as many domain-specific knowledge structures, and so processing is unrefined and based primarily on the recognition of distinctive surface features, hence their inferior performance, especially for stimuli presented in PLD (see Chapters 3 and 4).

The first two experiments presented in Chapter 2 provided evidence to suggest that when attempting to detect familiarity, skilled participants perceive crucial information based upon relative motions between features. Until relatively recently however, less was known about which features are particularly important when making these judgements. To address this issue, Williams and colleagues (e.g., Williams et al., 1994, 2006; Williams & North, 2009; North et al., 2009, 2011) conducted a series of experiments employing a number of different experimental techniques, to suggest that the relational information between central offensive features is important when attempting to detect familiarity within soccer action sequences. Experiment 3 of Chapter 2 provided further support for the importance of centrally located features to successful recognition judgments. More specifically, relative motions between features in two different central locations (midfield and offence) appear critical for experts to perceive meaning and structure to inform their recognition decisions. Clearly, these findings have significant practical implications, the nature of which are discussed later on.

In order to further explore the importance of central offensive players to familiarity-based judgments in soccer, Chapter 3 adopted a somewhat unique approach by occluding extraneous information available to the performer during scene recognition, to determine whether structure could still be perceived from the relative motion information remaining between ‘key features’ in the visual display. In keeping with extant literature (e.g., Williams et al., 2006), as well as findings from Chapter 2, skilled players were able to perceive familiarity when just the two central offensive players were presented (Condition 2), whereas no skill-based differences were reported when irrelevant sources of information were presented (i.e. peripheral players – Condition 1). This finding provides support for the importance of relative motion information between central offensive players when attempting to detect familiarity within dynamic action sequences. It could also be argued that the removal of relative motion information between extraneous features enabled the skilled participants to focus specifically on only the relevant sources of information (i.e. central forward players), thereby reducing the amount of information that had to be attended to during recognition. A similar interpretation may be garnered from the literature on change-detection, which has reported an improvement in performance for American football (e.g., see Laurent, Ward, Williams, & Ripoll, 2006) and basketball (Werner & Thies, 2000) respectively, when semantically irrelevant information is changed or distorted within the display.

Evidence was also provided to suggest that skilled players encode not only the relative motion between central offensive features, but also the player in possession of the ball (condition 3), given the skill advantage was increased further when a target feature was included against which these relative motions could be judged against. This provides tentative support for extant literature in the field, with eye-movement data from the work of North and colleagues (2009) implying that an important task when attempting to detect familiarity, is to quickly locate the position of the ball, since most information is likely to be relative to its position on the field. After location of the ball had been detected, skilled participants were less guilty of 'ball watching' preferring to focus their gaze more broadly on the positions and movements of players 'off the ball', namely central offensive features. Other soccer-specific research examining the effect of task constraints on visual search behaviour has demonstrated how in more time-constrained situations (e.g., 3 vs. 3 on the edge of the penalty area), skilled players fixate their gaze centrally, typically on the ball or player in possession of the ball, and use peripheral vision to monitor movements ‘off the ball’ (Williams & Davids, 1998; Vaeyens et al., 2007a, b). The use of these so-called ‘visual pivots’ has also been reported in other sports (e.g., see Ripoll, 1991; Williams & Elliot, 1999), as well as non-sporting domains. For example, Charness and colleagues (2001) found that in check detection situations in chess, the ‘King’ becomes a central organising feature with experts then making ‘visual pivots’ between other salient pieces to facilitate accurate pattern perception to inform their next move. Although comparisons can be made to similar pattern-recognition research, it should also be noted that with no process tracing measures employed in Chapter 3 (and throughout the thesis), no clear conclusions can be drawn from the data, specifically regarding which display features skilled participants encoded to inform their recognition judgments. Nevertheless, the skill-based differences observed for conditions 2 and 3 suggest that skilled performers only need to fixate on a select few stimuli within a display in order to make successful recognition judgments, supporting similar observations reported in both chess (see Bilalic et al., 2010) and face recognition (see Royer et al., 2015).

As discussed previously, findings from Chapter 3 may be explained by Dittrich’s Interactive Encoding Model (1999). A similar yet alternative interpretation to account for the skilled-based differences in recognition accuracy is provided by Ericsson and Kintsch’s (1995) LTWM theory. According to this model, experts develop elaborate task-specific retrieval structures in long-term memory as a result of extended deliberate practice within a domain, enabling attention to be directed to only the most important information sources within a visual display. These complex information structures are accessible through cues held in the short-term memory. Once activated, the appropriate retrieval structure is employed to interpret and evaluate future situations and decide upon an appropriate response (Ericsson & Kintsch, 1995; Ericsson et al., 2000). Findings from Chapters 2 and 3, suggest that the functional relations between the central offensive players relative to the location of the ball were sufficient to stimulate these complex retrieval structures in the long-term memory. Once activated, and despite only limited sources of information presented in isolation, skilled performers were successfully able to judge the observed display (micro patterns) in relation to the previously encountered stimuli (macro pattern) to facilitate their pattern matching/recognition judgments. In contrast, and given their comparative lack of experience, it is proposed that less-skilled performers have fewer and/or less refined representations in their long-term memory, and were thus impaired in their ability to attribute meaning to the relational information in the presented stimuli, hence their inferior recognition performance.

The ability of skilled performers to perceive familiarity within the presented stimuli when only the minimal essential information is presented, provides an intriguing consideration from a practical perspective. PLDs are often used in observational learning and rehabilitation settings to teach or relearn skills (e.g., Hayes et al., 2005). Some researchers propose that PLDs may be more useful than video when acquiring a co-ordinated movement pattern (e.g., Scully & Carnegie, 1998), as non-essential information is removed, presenting movement in its simplest terms (Cutting and Profitt, 1982). This subsequently facilitates visual attention to key features, reducing the processing demands necessary to perceive the critical movement invariance within a demonstration (Hayes et al., 2005). Although findings regarding the efficacy of PLDs over video have proved equivocal (e.g., Scully & Carnegie, 1998; Al-Abood, Davids, Bennett, Ashford, & Martinez-Marin, 2001; Horn, Williams, & Scott, 2002), North et al. (2011) found that when attempting to detect familiarity in soccer action sequences, skilled performers made significantly more references to attacking runs/movements than less-skilled players for the PLD clips, whereas no skill-based differences for these verbalisations were observed for the normal film clips. In the view of the aforementioned observational learning literature, it was subsequently argued that presenting patterns of play in PLD may actually highlight the critical information and facilitate the players' attention towards the movement of the central offensive players. From these observations, an interesting issue is whether PLDs could be used to highlight key relative motions within the visual display to try and improve familiarity perception in team-ball games. Although attempts have been made in the present thesis to train pattern-recognition skill by drawing the learners' attention to the relative motions between key features, normal film sequences were employed (see Chapter 5). The use of PLDs to highlight this information therefore provides an interesting area of future research.

Chapters 2 and 3 specifically examined the nature of information underpinning skilled familiarity perception by manipulating perceptual stimuli in the visual display and examining skill-based differences in familiarity perception for the presented information using a recognition paradigm. Several researchers have proposed that the ability to recognise patterns of play is crucial to anticipation in team sports (e.g., Abernethy et al., 1994; Williams & Davids, 1995). Anticipation in dynamic team games has however been shown to be dependent on a range of perceptual-cognitive skills, such as advance cue utilisation, visual search behaviour, and situational probabilities (e.g., Roca et al., 2011; 2013). Moreover, Williams and Ward (2007) suggest that these skills are not mutually exclusive and are likely to interact with each other in a dynamic and evolving manner to facilitate anticipation in the competitive setting. Chapter 4 therefore attempted to examine the relative importance of both pattern-recognition and postural cue usage to anticipation in soccer. In line with the findings of Roca et al. (2013), evidence was provided to suggest their importance may vary as a function of the situational task constraints. More specifically, and given the skill-based differences observed for the far PLD action sequences, skilled players appeared to rely predominantly on the identification of familiarity in patterns of play when making anticipation judgments in this task situation. In contrast, they demonstrated a significant decrement in anticipation performance for the near PLD stimuli, providing anecdotal evidence to suggest that pattern-recognition skill was no longer the primary perceptual-cognitive skill constraining anticipation performance in this viewing condition. Although it was not possible to ascertain the exact nature of information encoded in the film sequences with no process tracing measures employed, previous research evidence suggests that when the action becomes more localised and time-constrained, skilled players rely more heavily on the postural orientation of opponents or team-mates (especially the player in possession of the ball), whilst formulating a priori expectations as to what their opponents were likely to do in advance of the actual event (situational probabilities) (e.g., see Roca et al., 2013). From a practical perspective, these findings have significant implications for the way in which researchers try to capture and examine perceptual-cognitive skills in future. Although the recognition paradigms in Chapters 2 and 3 provided important insights into the minimal essential information underlying skilled recognition, such techniques may not be sufficiently representative of the complex perceptual-cognitive processes performers engage in when making actual anticipation judgments (Ericsson & Lehmann, 1996). Findings reported here would therefore advocate against using reductionist approaches when examining expert performance, given the dynamic interaction between the different perceptual-cognitive skills when making anticipation judgments.

In addition to contributing and developing theoretical understanding, findings from Chapters 2, 3 and 4 provide a conceptual backdrop for the type of training that could be used to facilitate performance enhancement in this area. When training central defenders, coaches may be better advised to create task manipulations that constrain the learner to focus their attention on the relative motion and interactions between central offensive players and the ball, as oppose to isolated features. Findings from Chapter 4 would suggest that this is particularly important when the action is far away in the opposite half of the pitch. Training drills such as pattern play whereby the opposition keep possession of the ball for long periods may be a particularly useful practice, allowing the defenders to constantly monitor offensive movements 'off the ball', while making visual pivots to the player on the ball (Williams & Davids, 1998;

Vaeyens et al., 2007a, b). Equally, and when the relative distance between the ball and the defender is reduced, findings suggest that postural cue information gains added significance, as evidenced by the Display x Task Situation interaction observed. Under these circumstances, more task-specific training drills that reduce the number of players (e.g., 1 vs. 1, 2 vs. 1, and 3 vs. 2) would appear to be more useful when trying to improve anticipatory performance in such time-constrained situations.

As highlighted in Chapters 1 and 5, many researchers have attempted to improve performance through perceptual training programmes, across a variety of sporting domains. Typically however, these studies have been confined to the perceptual-cognitive skill of advance cue utilisation, for closed situations, such as the penalty flick in field hockey (e.g., Williams et al., 2002). Despite its perceived importance to high-level performance in soccer (e.g., Ward & Williams, 2003), few, if any, have examined whether pattern-recognition skill can be facilitated through practice and instruction in open, whole-sided environments (Williams & Hodges, 2005). With the previous chapters of work identifying the minimal essential information underlying skilled familiarity perception in such stimuli, the different methods of highlighting this information were considered based on previous perceptual training literature (i.e., implicit vs. explicit instructional techniques, for reviews see, Jackson & Farrow, 2005; Williams & Grant, 1999). A final point of interest pertained to whether developing the ability to recognise sequences of play would lead to a significant improvement in anticipation.

The results from this study are reported at the start of this chapter. To recap, participants were significantly more sensitive in their recognition decisions at post-test compared to pre-test, but with no main effect for Group or Group x Training interaction, the observed training effect was most likely a result of increased test familiarity and/or confirmation bias. In a similar vein, null effects were also reported for anticipation performance. Although disappointing, the present thesis marked an initial attempt to train pattern-recognition skill in soccer, and was therefore somewhat exploratory in nature. Given researchers have induced significant training effects for other perceptual-cognitive skills (i.e. advance cue utilisation), it is feasible that with improved methodological considerations, the ability to detect familiarly in patterns of play could still be improved through extended practice and instruction. Potential limitations to account for the reported null findings are highlighted in the next section, as well as future research recommendations.

**Limitations and Directions for Future Research**

Since its inception by Charness in the game of chess (1976, 1979), the recognition paradigm has been extended to a multitude of sporting domains to examine expert performance. This approach has consistently induced skill-based differences, and is reported to measure an important component of anticipation (Abernethy et al., 2005; Williams & Davids, 1995). It was consequently used in the current thesis to provide experimental control when examining the underlying mechanisms facilitating skilled familiarity perception in soccer. Researchers have argued however, that such paradigms fail to take into consideration ecological validity and/or representative task design (e.g., Williams, 2009; Pinder, Davids, Renshaw, & Araujo, 2011). While a consistent main effect for skill was obtained with a degree of experimental control, this criticism can feasibly be levied against the current programme of work, given participants were sat down whilst undertaking the testing procedures, and made pen and paper responses to the presented stimuli. In order to increase the possibility of identifying critical expert-novice differences, researchers have advocated that testing be carried out under controlled situations that replicate the performance environment as closely as possible (e.g., Abernethy, Thomas, & Thomas, 1993). Given the dynamic temporal constraints and complex motor action demands of soccer, the testing protocols employed were clearly not indicative of the way in which a defender would 'read the play' in a game situation (for a review, see van der Kamp, Rivas, van Doorn, & Salvesbergh, 2008).

The action sequences were filmed from a slightly elevated perspective that ensured the entire field of play was visible and that information from wide areas was not excluded. This standpoint was considered as close as possible to a central defenders typical view in a game situation, and has been shown to accurately capture expert performance (see Ripoll, Petit, & Le Troter, 2005). In reality however, it is plausible that even the central defender will only see a subset of the overall pattern, given the constant interaction between team-mates and opponents. Thus, and even though construct validity has been established for the use of such clips in previously published reports (e.g., North et al., 2009, 2011; Ward & Williams, 2003; Williams et al., 2006), future researchers are encouraged to develop a more realistic viewing perspective. In view of the first stage of the 'Expert Performance Approach' (Ericsson & Smith, 1991), Roca et al. (2011; 2013) employed action sequences that were filmed from the first person-perspective, in order to develop more representative task design and increase the likelihood of eliciting skill-based differences.

The ability of performers to use information from the environment to support action is predicated on an accurate and efficient relationship between perceptual and motor processes (Le Runigo, Benguigui, & Bardy, 2005), a process referred to as perception-action coupling (Goodale & Milner, 1992; Milner & Goodale, 1995). As the paradigms employed did not require participants to move in response to the presented stimuli, the removal of such environmental constraints may have forced 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). Thus, researchers looking to replicate any of the experiments reported here, are strongly advocated to develop more realistic protocols to better simulate the performer's competitive environment, constraining individuals to make actual bodily responses to maintain important perception-action coupling links (Goodale & Milner, 1992; Milner & Goodale, 1995). With recent advances in technology, virtual reality paradigms may provide an interesting area of future research for studying expert performance in action. For example, Bideau et al. (2003) showed that an interactive, virtual handball court with a realistically animated handball player throwing the ball towards goal, elicited expert handball goalkeeper responses similar to those observed in the real-world.

In addition to the absence of a physical response from the participants, another limitation pertains to the lack of temporal constraint throughout each testing paradigm. For example, the action sequences in Chapter 3 were in 5-seconds in length, with an additional 2-second response time, followed by a 5-second inter-trial interval. Thus, participants actually had a full 12-seconds in which they could make their familiarity-based response. Clearly, in the dynamic game of soccer, players are not afforded with such a prolonged period of time in which to perceive familiarity. Similarly, and with regards to the anticipation paradigms, freeze-frames were employed at the end of each action sequence, to allow participants to predict final pass destination of the player in possession of the ball. This may have actually enabled participants to extract additional information over and above that extracted during the action sequence, and was therefore not indicative of anticipation judgments in a game situation (see Ryu et al., 2015). Future researchers are therefore strongly advised to better replicate performance environment by including a measure of temporal constraint. This could be achieved by a timed response system that calculates decision speed and cuts off after clip occlusion. Although this may create a speed-accuracy trade-off (Fitts, 1954; Abernethy et al., 2005), in many situations the ability to act quickly (i.e., before ball flight) provides a significant advantage over an opponent, and is therefore a prerequisite to expert performance (Triolet, Benguigui, Runigo, & Williams, 2013). Thus, and in addition to measuring recognition/anticipation accuracy (or sensitivity), speed of response measures should increase the likelihood of eliciting greater skill-based differences, affording a more accurate depiction of overall performance levels (Travasso, Araujo, Davids, O'Hara, Leitao, & Cortinhas, 2013).

The lack of temporal constraint within the action sequences highlights another potential confound pertaining to the duration of experimental stimuli throughout the programme of work. To this end, Chapter 2 presented participants with action sequences that were 3-seconds in length, given previous research has provided evidence to suggest that in continuous dynamic sports, structure emerges in very brief discrete moments. Specifically the final 1 to 3-seconds preceding a critical attacking event such as a penetrative pass or attempt at goal (North and Williams, 2008; Féry & Crognier, 2001). In contrast, and given the extensive occlusion procedures employed, presentation time was extended in Chapter 3 (to 5-seconds) in an attempt to facilitate memory performance by providing more contextual information (cf., Paull & Glencross, 1997; Vincente & Wang, 1998). In hindsight however, this was somewhat counterintuitive, as the main aim of the study was to determine whether familiarity could still be perceived when only the minimal essential information was presented, irrespective of presentation time. Action sequences in Chapter 4 were also 5-seconds in length, followed by a 2-second freeze-frame to allow participants to make an anticipatory judgment, increasing overall presentation time to 7-seconds. In keeping with Chapter 3, the increased exposure was intended to present more contextual information (i.e., intra and inter-individual relational information) in order to facilitate expert memory and thus anticipation. For example, Paull and Glencross (1997) demonstrated that skilled baseball batters were more accurate in anticipating the type of delivery a pitcher would throw when presented with increasing amounts of contextual information prior to the event. Nevertheless, Vicente and Wang (1998) propose that the constraints to expert performance are unique to each problem domain, meaning increased exposure time may not necessarily constrain expert memory performance in other fields. In this regard, soccer involves complex interactions between team-mates, opponents and the ball, as discrete moments of order (structure) may be interspersed by periods of disorder or relatively random behaviour (Grehaigne, Bouthier, & David, 1997). The implication being that an increased exposure time may not necessarily provide access to additional structural information, and therefore may not be a constraint to memory performance for such stimuli. Williams and North (2008) provided evidence to support these assumptions, employing a similar methodological design (as well as stimuli) to that observed throughout the present programme of work. Specifically, skilled participants demonstrated better recognition and anticipation performance when patterns of play were presented for 3-seconds, in comparison to those that were 1 and 5-seconds in length respectively. Although the methodological design for Chapters 2, 3 and 4 were slightly different, the lack of control measures pertaining to the duration of experimental stimuli was certainly a limitation. Clearly, future research needs to address these issues in order to maintain consistency and validate any reported findings.

In order to gain a better understanding of the specific sources of information governing skilled pattern-recognition, chapters 2 and 3 employed a spatial occlusion procedure. If performance deteriorated when certain features were occluded (in comparison to a control condition), it was deduced that those elements within the pattern were critical for maintaining the underlying structural relationships that underpin expert pattern perception (Williams et al. 1999). Although this technique has proved instrumental in previous research of a similar ilk (e.g., Williams et al., 2006), by removing certain elements within a pattern, it is possible that both the overall structure of said pattern and the nature of the interactions between individual features are altered significantly, even when just a single feature is occluded (Huys et al., 2009). Thus, any decrement in recognition performance may be due to the changes in the relationship between the occluded display feature(s) and the remaining elements, rather than being solely attributed to the feature(s) that was occluded (Huys et al., 2009). From these observations, it cannot be concluded with absolute certainty that the centrally located features in Chapter 2 were solely responsible for the decrement in skilled recognition performance when the two central offensive players (condition 2) or two central midfield players were occluded (condition 3).

Chapter 3 attempted to validate the importance of centrally located features by examining whether skilled participants were able to recognise global patterns on the basis of micro patterns between a limited number of key display features. Although findings provided further support for the potential importance of central offensive players to pattern-recognition skill in soccer, the lack of a suitable control condition is an unfortunate limitation. In order to ensure the spatial occlusion procedure itself was not the cause of any decrement in performance (i.e. for condition 1 when only two peripheral players were shown), researchers attempting to build on this work are strongly advised to include a fourth condition where no occlusion procedures have been undertaken (i.e. 11 vs. 11 action sequences). This additional condition would provide a comparable reference point for any skill-based differences evident across the three other experimental conditions, while validating any potential findings.

The skill-based differences elicited for recognition accuracy/sensitivity in Chapters 2 and 3, provided evidence of the minimal essential information underlying expert performance in soccer. With regards to the less skilled players, their inferior performance was consistently attributed to their tendency to rely on superficial surface-level features when making familiarity-based judgments (e.g., Williams et al., 2006). They did however demonstrate unusually low levels of performance throughout, as evidenced by the reported *d'* values. Although this was expected for Chapters 3 and to some extent 4, given PLD action sequences were employed, their scores were indicative of a guesswork approach, meaning it was not possible to draw conclusions about the nature of information used to make recognition judgments. As detailed earlier, a logical explanation pertains to their impoverished cognitive knowledge structures, which made it very difficult to encode and store information during the initial viewing phase, when compared to their skilled counterparts. Subsequent familiarity-based judgements were therefore impaired as the participants were forced to guess rather than to make judgements against information stored in memory. This account would concur with the previously discussed models of expertise, namely the Interactive Encoding Model (Dittrich, 1999), and the LTWM theory (Ericsson & Kintsch, 1995).

An alternative explanation to account for the poor performance of the less-skilled players in Chapter 2 especially, is that the subtle manipulations between the experimental conditions posited that they were unable to perceive the differences between new and previously seen stimuli, meaning the recognition paradigm was not a sufficiently sensitive task. In their meta-analysis of research into perceptual–cognitive expertise, Mann et al. (2007) concluded that methodologies requiring the same encoding, retrieval, and application of information, such as predictive anticipation tasks and field-based methods, were significantly more sensitive than recognition and recall-based measures. In support of this, Ericsson and Lehmann (1996) describe such techniques to not be sufficiently representative of the complex perceptual-cognitive processes performers engage in when making actual anticipation judgements. More specifically, individuals are required to anticipate future action requirements rather than to identify a particular pattern of play, and consequently, such paradigms may only capture a related function or skill. As discussed earlier, and although the recognition paradigm provided a reliable tool to identify the nature of information underlying skilled familiarity perception in soccer, future research may wish to move beyond such reductionist approaches when examining expert performance (Williams, 2009).

In view of this, Chapter 4 provided further evidence of the potential interaction between the different perceptual-cognitive skills during performance, with the relative importance of each varying as a function of the specific situational task constraints (i.e. near vs. far) (e.g., Williams & Ward, 2007). According to Newell (1986), a number of other factors influence the way in which the perceptual-cognitive skills interact with each other to facilitate anticipation in sport. A potentially interesting area of future research would be to examine how factors associated specifically with the player effects the way in which information is extracted from the visual display, and thus the perceptual-cognitive skills constraining performance. Although a considerable shift from the current programme of work given the absence of process tracing measures and simple pen and paper responses employed, eye-movement data has demonstrated how search behaviour can deviate under conditions of excessive physiological fatigue and emotional stress, as a consequence of peripheral narrowing or hypervigilance (e.g., Janelle et al., 1999; Williams & Elliott, 1999; Vickers & Williams, 2007). In such circumstances, the relative interaction between the different perceptual-cognitive skills could be effected considerably, as the central defender becomes less aware of the runs and movement of players ‘off the ball’ (pattern-recognition) and focuses more on the player in possession of the ball (postural cue usage) which could in turn, influence anticipatory judgments, and thus performance. To date, very few researchers have attempted to identify the different constraints (e.g. emotion) and how they influence the importance of these perceptual-cognitive skills.

The ability to read the game as a central defender is an important facet, hence why pattern-recognition skill is considered so crucial to expert performance (Abernethy et al., 2005). For this reason, Chapters 2 and 3 attempted to identify the minimal essential information underling skilled pattern perception. As evidenced in Chapter 4 however, the importance of each perceptual-cognitive skill to anticipation performance may vary according to the situational task constraints. Another interesting area of future research would be to examine their relative interaction as a function of the positional role within a team. For example, attacking players are typically more creative given their need to open up the opposition and fashion a scoring opportunity. The extent to which they rely on pattern-recognition over situational probabilities, postural cue usage and general decision-making skill, will likely vary when compared to a central defender. Williams, Ward, Smeeton, and Ward (2008) examined this issue in greater detail, by comparing the anticipation performance of players in different positional roles within a team. In all there were four experimental groups; expert offensive players, similarly skilled defensive players, novice offensive players, and equally matched defensive players, all of whom completed a film-based anticipation test. Findings demonstrated a main effect for skill as the expert players were significantly more accurate than their less skilled counterparts. More interestingly however, the Skill x Position interaction revealed that the expert defenders were significantly more accurate than their expert offensive counterparts. Given a defender's primary task is to anticipate the actions of their opponents, findings were attributed to an increased likelihood of developing more refined, position-specific cognitive representations to facilitate anticipation skill (Didierjean & Marmeche, 2005; Ericsson & Kintsch, 1995). In contrast, attacking players typically spend more time in possession of the ball, meaning other skills such as decision-making, are likely to take precedence over anticipating the actions of an opponent. Although it seems fairly logical that players in different positional roles will possess slightly different skill-sets, empirical evidence supporting this within the expertise literature, is somewhat limited. This has important implications from a practical perspective, given perceptual training programmes could be tailored to different positions on the field. Even subtle tactical adjustments, such as the central defender moving to full-back (i.e. in the event of an injury), will impose different constraints on the player, where the movement of the central offensive players may not be so critical to reading the play. The key perceptual-cognitive skills within a specific positional role, and their relative interaction depending on the situational task constraints, poses an intriguing area for future research.

The use of process tracing measures has become increasingly common to garner a better understanding of the specific sources of information skilled players perceive and encode in the visual display to facilitate recognition, anticipation, and decision-making judgments, respectively (e.g., Williams & Davids, 1998; McRobert, Williams, Ward, & Eccles, 2009). Whilst the experiments reported in the current thesis manipulated the presented stimuli (i.e., spatial occlusion technique) in an attempt to identify the nature of information underpinning skilled recognition and anticipation performance, a logical step forward would be to collect eye-movement data and verbal protocol analysis to validate the reported findings. For example, Chapter 4 could only provide anecdotal evidence of the potential interaction between the different perceptual-cognitive skills across task constraints, by controlling the amount of information presented to the participants (i.e., video vs. PLD action sequences). Although the data appeared to support extant literature (e.g., Williams et al., 2006), complementary process tracing measures would help to substantiate findings, as evidenced in earlier research of a similar ilk (e.g., Roca et al., 2013; North et al., 2009; 2011).

As previously alluded to, Chapter 5 failed to report any findings of significance pertaining to whether pattern-recognition skill can be trained, the most effective instructional method of doing so, and if potential training effects transferred to anticipation performance. Although possible reasons to account for the null effects have already been discussed, there are a several other points of interest to consider for future research in this area. For example, there may have been a potential lack of power in the findings due to the relatively small number of participants in each experimental group ($n = 16$). Moreover, and while the participants were ability-matched before undertaking the intervention, high variability in the data (as evidenced by the large standard deviations), may have contributed towards the overall low scores reported. There were however some very slight trends observed between experimental groups, which as discussed in Chapter 5, may have gained significance with an increased training load. In this regard, the intervention included 4 blocks of 30 training clips ($n = 120$), whereas in a similar study for a decision-making task in American Football (Kirlik et al., 2006), participants were subjected to 12 blocks of 36 training clips ($n = 432$). Although the optimal frequency and scheduling of perceptual training sessions remains unclear (e.g., McMorris and Hauxwell, 1997), researchers looking to build upon this work, are advised to increase the number of training stimuli, as well as participants, in order to improve the likelihood of inducing meaningful training effects.

Despite the exploratory nature of the intervention to account for the paucity of literature concerning the susceptibility of pattern-recognition skill to training, there were other notable areas for improvement. For example, a major limitation pertains to the absence of a transfer test. This particular critique is a very important one, as improvements observed in the laboratory are essentially irrelevant if they fail to transfer to a game situation. To this end, a growing number of empirical studies have demonstrated how anticipatory skills learned using video simulations generalise to on-court situations (e.g., Hopwood, Mann, Farrow, & Nielsen, 2011; Williams, Ward, & Chapman, 2003). Given the inherent complications of measuring perceptual-cognitive skill in competition, especially for invasive sports, Williams and Grant (1999) suggest both quantitative and qualitative evaluation techniques may be employed to examine the issue of transfer. For example, the subjective appraisal of the coach pre and post the intervention using behavioural assessment scales, may prove fruitful in determining the effectiveness of the training program (e.g., French & Thomas, 1987; Oslin, Mitchell, & Griffen, 1998). Additional video analysis techniques may also be employed to substantiate personal opinion with objective evaluation. In this regard, sophisticated match-analysis systems such as

‘*Prozone*’ and ‘*Opta*’, are becoming almost mandatory at an elite level, in order to quantify sporting performance within team-based games. Typically, physical and technical data is collated *in situ* using high-speed cameras and complex tracking systems, to provide a comprehensive overview of both individual and team performance. With regards to assessing the efficacy of a perceptual training programme for the central defender in a game situation, key performance indicators such as the number of tackles and interceptions won/made, could provide a useful measure of any potential improvement in perceptual-cognitive skill. With perceptual training research still relatively embryonic, the use of performance analysis to validate its effectiveness may be some years down the line yet, but certainly provides an interesting area of future research to examine the issue of transfer within a competitive environment.

In view of the earlier discussed issue regarding the importance of ecological validity when studying expert performance (Williams, 2009), researchers have also raised concerns over the use of representative tasks for perceptual training purposes (e.g., Pinder et al., 2011; van der Kamp, Rivas, van Doorn, & Salvesbergh, 2008). In a recent meta-analysis for decision-making expertise in sport, Travasso et al. (2013) found that expert-novice differences are directly related to how close the action undertaken in a simulated environment is to the actual action required in sport (see also Mann et al., 2007). In line with the criticisms levied at the earlier chapters of work regarding the simplistic response protocols and lack of perception-action coupling, researchers attempting to replicate the perceptual training programme reported here, are strongly advised to develop more realistic task design to increase the possibility of transfer to the competitive setting. With certain modifications, such as the use of high-definition film clips, more sophisticated editing techniques to highlight runs/movements of players in the training footage, first person viewing perspective (see Roca et al., 2011), and requisite movement responses from the participants (e.g., Travassos et al., 2013, Abernethy et al., 1993), ecological validity could certainly be improved, which may increase the likelihood of finding meaningful training effects. Nevertheless, it is not always possible to exactly replicate the performance setting, especially within a training programme explicitly designed to highlight relative motion information between central offensive players in the dynamic and interactive game of soccer. Researchers are therefore encouraged to create training environments that are consistent with those experienced in game situations, whilst maintaining some form of balance to ensure internal validity as well as experimental control when examining expert performance in sport (Causer, Barach, & Williams, 2014).

In this regard, and despite the perceived importance of maintaining perception-action coupling when training perceptual-cognitive skill (e.g., Pinder et al., 2011), some researchers have improved anticipation performance without the need for any direct link between perception and motor function (e.g., Ranganathan & Carlton, 2007). For example, Williams et al. (2004) examined the relative efficacy of on-court perception-action training (physically returning the serve) and perception-only (verbally responding to serve direction) training in improving anticipation skill for a group of novice tennis players. Findings showed how the perception-action and perception-only groups significantly improved their anticipation performance from pre to post-test, compared to participants who received technical instruction (control group). Moreover, no significant differences were observed between the two perception groups, implying that either mode of training may be effective in enhancing perceptual skill in sport. The notion of improving performance without the need for physical practice is extremely interesting, especially when the performer faces a long spell out injured, which may be particularly useful for younger players during their developmental years. Similarly, perceptual training techniques could be used when travelling to competition, undertaking additional self-regulated training at home, or simply recovering from training (Williams & Ford, 2013). From these observations, it seems clear that the relative importance of perception-action coupling to perceptual training interventions, requires further clarification (for a detailed review, see Craig, 2014).

The aforementioned limitations provide only a brief overview of how the training study employed in the current thesis could be improved, alongside directions for future research. Needless to say, there are many other factors to consider when designing a perceptual training programme, such as the most appropriate age (e.g., McPherson & Thomas, 1989) and stage of learning (novice, intermediate, advanced) interventions should be directed to (e.g., Alessi, 1988; Andrews, 1988). Increasingly, researchers are developing the tenets from the motor skills literature to explore how practice should be structured for effective perceptual learning (see Lee, Chamberlin, & Hodges, 2001). Of particular interest is the *contextual interference* effect (CI) in the acquisition of motor skills (Magill & Hall, 1990), which consistently demonstrates how practice involving high CI (i.e. random schedule) results in poorer performance during acquisition, but superior long-term learning and transfer of skills, when compared to low CI conditions (i.e. blocked schedule; Lee, 2012). An interesting concept is whether this theory extends to training perceptual-cognitive skill in sport (e.g., Memmert, Hagemann, Althoetmar, Geppert, & Seiler, 2009). A recent study by Broadbent, Causer, Williams, and Ford (2015), provided strong evidence for the importance of high CI in the learning of three distinct tennis shots (groundstroke, volley and smash). Findings showed how the random practice group reported significantly higher response accuracy in the retention test, and significantly reduced their decision time in the subsequent on-court based transfer test, when compared to the blocked practice group. Although further research is required in this area, from a practical perspective the aforementioned findings could prove extremely beneficial in ensuring long-term learning and transfer of perceptual-cognitive skills in sport.

### Concluding remarks

In conclusion, the results presented in this thesis have provided evidence of the nature of information underpinning pattern-recognition in full sided, open play, soccer environments. Findings demonstrate that skilled players encode structure by perceiving relative motion information between features within the presented stimuli. More specifically, the relative motions between the central offensive players as well as the player in possession of the ball, appear crucial when attempting to detect familiarity within team-based sports. In addition, the current programme of work has provided further evidence of the relative interaction between the different perceptual-cognitive skills when making anticipation judgments, and how their importance may vary as a function of the unique constraints of the task. With a more complete understanding of the nature of information underpinning skilled familiarity and anticipation, an exploratory attempt was made to train the two constructs using a perceptual training programme. Although null effects were reported, it is hoped these will act as a catalyst for other researchers examining performance enhancement in this area, especially for pattern-recognition skill. Overall, the thesis has extended the perceptual-cognitive expertise literature, offering both practical and theoretical implications, as well as avenues for future research.

# Chapter 7: References

Abernethy, B. (1986). Enhancing sports performance through clinical and experimental optometry. *Clinical and Experimental Optometry*, 69, 189-196.

Abernethy, B. (1987). Anticipation in sport: a review. *Physical Education Review*, 10, 5-16.

Abernethy, B. (1989). Expert-novice differences in perception: How does the expert have to be? *Canadian Journal of Sport Science*, 14, 27-30.

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

Abernethy, B. (1993). The nature of expertise in sport. *Paper presented at the 7th International Society of Sport Psychology Conference, Lisbon, Portugal.*

Abernethy, B. (2001). Attention. In R. N. Singer, H. A. Hausenblas, & C. M. Janelle (Eds.). *Handbook of sport psychology* (pp. 53-85). New York: John Wiley & Sons.

Abernethy, B., Baker, J., & Cote, J. (2005). Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology*, 19, 705–718.

Abernethy, B., Gill, D. P., Parks, S. L., & Packer, S.T. (2001). Expertise and the perception of kinematic and situational probability information. *Perception*, 30 (2), 233-252.

Abernethy, B., Maxwell, J.P, Masters, R.S.W., van der Kamp, J., & Jackson, R. (2007). Attentional processes in skill learning and expert performance. In G. Tenenbaum and R. Eklund (Eds.), *Handbook of Sport Psychology* (pp. 245-263). New York: John Wiley & Sons.

Abernethy, B., Neal, R. J., & Koning, P. (1994). Visual-perceptual and cognitive differences between expert, intermediate, and novice snooker players. *Applied Cognitive Psychology*, 8, 185-211.

Abernethy, B., Poolton, J.M., Masters, R.S., & Patil, N.G. (2008). Implications of an expertise model for surgical skills training. *ANZ Journal of Surgery,* 78 (12), 1092-1095.

Abernethy, B., & Russell, D. G. (1984). Advance cue utilization by skilled cricket batsmen. *Australian Journal of Science and Medicine in Sport*, 16, 2-10.

Abernethy, B., & Russell, D. G. (1987). The relationship between expertise and visual search strategy in a racquet sport. *Human Movement Science*, 6, 283-319.

Abernethy, B., Schorer, J., Jackson, R. C., & Hagemann, N. (2012). Perceptual training methods compared: The relative efficacy of different approaches to enhancing sport specific anticipation. *Journal of Experimental Psychology: Applied*, 18 (2), 143-153.

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: Elsevier Science Publishers.

Abernethy, B., Wann, J. P., & Parks, S. (1998). Training perceptual-motor skills for sport. In B. C. Elliott (Ed.), *Training in Sport: Applying Sport Science* (pp. 1–68). Chichester: John Wiley & Sons.

Abernethy, B., & Wood, J. M. (2001). Do generalised visual training programmes for sport really work? An experimental investigation. *Journal of Sports Science*, 19, 203-222.

Abernethy, B., Wood, J. M., & Parks, S. (1999). Can the anticipatory skills of experts be learned by novices? *Research Quarterly for Exercise and Sport*, 70 (3), 313-318.

Adolphe, R. M., Vickers, J. N., & Laplante, G. (1997). The effects of training visual attention on gaze behaviour and accuracy: a pilot study. *International Journal of Sports Vision*, 4, 28-33.

Al-Abood, S. A., Davids, K., Bennett, S. J., Ashford, D., & Martinez-Marin, M. (2001). Effects of manipulating relative and absolute motion information during observational learning of an aiming task. *Journal of Sports Sciences*, 19, 507-520.

Alain, C., & Proteau, L. (1980). Decision making in sport. In C. H. Nadeau, W. R. Halliwell, K. M. Newell, & G. C. Roberts (Eds), *Psychology of Motor Behaviour and Sport* (pp. 465-477). Champaign, IL: Human Kinetics.

Alain, C., & Sarrazin, C. (1990). Study of decision-making in squash competition: A computer simulation approach. *Canadian Journal of Sport Science*, 15, 193-200.

Alain, C., Sarrazin, C., & Lacombe, D. (1986). The use of subjective expected values in decision making in sport. In D. M. Landers (Ed.), *Sport and elite performers* (pp. 1-6). Champaign, IL: Human Kinetics.

Alessi, S. M. (1998). Fidelity in the design of instructional simulators. *Journal of Computer Based Instruction*, 15, 40-47.

Allard, F., Graham, S., & Paarsalu, M. E. (1980). Perception in sport: Basketball. *Journal of Sport Psychology*, 2, 14-21.

Alt, M. (2011). Phonological working memory impairments in children with specific language impairment: where does the problem lie? *Journal of Communication Disorders*, 44 (2), 173-185.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89 (4), 369-406.

Anderson, J. R. (1987). Skill acquisition: compilation of weak-method problem solutions. *Psychological Review*, 94, 192-210.

Anderson, J. R, (1990). *The Adaptive Character of Thought*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Andrews, D. H. (1988). Relationship among simulators, training devices, and learning; a behavioural view. *Educational Technology*, 28 (1), 48-54.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: a proposed system and its control processes. *Psychology of Learning and Motivation*, 2, 89-195.

Baddeley, A. D. (1986). *Working Memory*. New York: Clarendon Press.

Baddeley, A. D. (1997). *Human Memory, Theory and Practice*. East Sussex, UK: Psychology Press, Taylor & Francis Group.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, 4 (11), 417-423.

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of Learning and Motivation*, 8, 47-89.

Baddeley, A. D., & Wilson, B. A. (2002). "Prose recall and amnesia: implications for the structure of working memory". *Neuropsychologia*, 40 (10), 1737-1743.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioural change. *Psychological Review*, 84 (2), 191-215.

Barclay, C. D., Cutting, J. E., & Kozlowski, L. T. (1998). Temporal and spatial factors in gait perception that influence gender recognition. *Nature*, 259, 557-558.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, D. J. (1991). Theory into practice: how do we link? In T. M. Duffy, and D. H. Jonassen (Eds), *Constructivism and Technology of Instruction: A Conversation* (pp. 17-35). Hillsdale, NJ; Lawrence Erlbaum.

Beek, P. J. (2000). Toward a theory of implicit learning in the perceptual-motor domain. *International Journal of Sport Psychology*, 31, 547-554.

Beek, P. J., Jacobs, D., Daffertshofer, A., & Huys, R. (2003). Expert performance in sport: views from the joint perspections of ecological psychology and dynamical systems theory. In J. L. Starkes and K. A. Ericsson (Eds), *Expert performance in Sports: Advances in Research on Sport Expertise* (pp. 321-342). Champaign, IL: Human Kinetics Publishers.

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: what governs choking under pressure? *Journal of Experimental Psychology: General*, 130 (4), 701 725.

Bideau, B., Kulpa, R., Menardais, S., Fradet, L., Multon, F., Delamarche, P., & Arnaldi, B. (2003). Real handball goalkeeper vs. virtual handball thrower. *Presence: Teleoperators & Virtual Environments*, 12, 411 –421.

Bilalic, M., Langner, R., Erb, M., & Grodd, W. (2010). Mechanisms and neural basis of object and pattern recognition: a study with chess experts. *Journal of Experimental Psychology: General*, 139 (4), 728-742.

Blättler, C., Ferrari, V., Didierjean, A., van Elslande, P., & Marmèche, E. (2010). Can expertise modulate representational momentum? *Visual Cognition*, 18 (9), 1253-1273.

Borgeaud, P., & Abernethy, B. (1987). Skilled perception in volleyball defence. *Journal of Sport Psychology*, 9, 400-406.

Brault, S., Bideau, B., Kulpa, R., & Craig, C. M. (2012). *Detecting deception in movement: the case of the side-step in rugby*. PlosONE, 7, e37494.doi:10.1371/journal.pone.0037494.

Breslin, G., Hodges, N. J., Williams, A. M., Curran, W., & Kremer, J. (2005). Modelling relative motion to facilitate intra-limb coordination. *Human Movement Science*, 24, 446-463.

Breslin, G., Hodges, N. J., Willia-ms, A. M., Kremer, J., & Curran, W. (2006). A comparison of intra- and inter-limb relative motion information in modelling a novel motor skill. *Human Movement Science,* 25, 753-766.

Broadbent, D. P., Causer, J., Williams, A. M., Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science*, 15 (4), 322-331.

Brownlow, S., Dixon, A. R., Egbert, C. A., & Radcliffe, R. D. (1997). Perception of movement and dancer characteristics from point-light displays of dance. *Psychological Record*, 47, 411-421.

Bruner, J. S. (1960). *The process of education*. Cambridge, MA; Harvard University Press.

Cañal-Bruland, R. (2009). Guiding visual attention in decision making – verbal instructions versus flicker cueing. *Research Quarterly for Exercise and Sport*, 80 (2), 369-374.

Cañal-Bruland, R., & Williams, A. M. (2010). Recognising and predicting movement effects: Identifying critical movement features. *Experimental Psychology*, 57, 320 326.

Carsten, O., Tight, M. R., Southwell, M. T., & Plows, B. (1989). *Urban accidents: why do they happen?* AA Foundation for Road Safety Research, Basingstoke, England.

Castiello, U., & Umiltà, C. (1990). Size of the attentional focus and efficiency of processing. *Acta Psychologica*, 73, 195-209.

Causer, J., Barach, P., & Williams, A. M. (2014). Expertise in medicine: using the expert performance approach to improve simulation training. *Medical Education*, 48 (2), 115 123.

Causer, J., Janelle, C. M., Vickers, J. N., & Williams, A. M. (2012). Perceptual training: what can be trained? In Hodges, H. J., and Williams, A. M. (Eds), *Skill Acquisition in Sport: Research, Theory and Practice* (pp. 306-324). London: Routledge.

Chabris, C. F., & Hearst, E. S. (2003). Visualization, pattern recognition, and forward search: Effects of playing speed and sight of the position on grandmaster chess errors. *Cognitive Science*, 27, 637–648.

Chapman, C. (2001). *Anticipating the penalty flick: training perceptual skills in hockey goalkeepers*. Unpublished doctoral dissertation. Liverpool John Moores University, Liverpool, United Kingdom.

Charness, N. (1976). Memory for chess positions: Resistance to interference. *Journal of Experimental Psychology*, 2, 641-653.

Charness, N. (1979). Components of skill in bridge. *Canadian Journal of Psychology*, 33, 1 16.

Charness, N., Reingold, E. M., Pomplun, M., & Strampe, D. M. (2001). The perceptual aspect of skilled performance in chess: Evidence from eye movements. *Memory and Cognition*, 29, 1146-1152.

Chase, W. G., & Ericsson, K. A. (1982). Skill and working memory. In G. H. Bower, (Ed.), *The Psychology of Learning and Motivation* (Vol. 16, pp. 1-58). New York: Academic Press.

Christina, R. W., Barresi, J. V., & Shaffner, P. (1990). The development of response selection accuracy in a football linebacker using video training. *The Sport Psychologist*, 4, 11 17.

Chun, M. M. (2000). Contextual cueing of visual attention. *Trends in Cognitive Sciences*, 4 (5), 170-178.

Cohn, T. E., & Chaplik, D. D. (1991). Visual training in soccer. *Perceptual and Motor Skills*, 72, 1238-1240.

Craig, C. (2014). Understanding perception and action in sport: How can virtual reality technology help? *Sports Technology*, 6 (4), 161-169.

Cutting, J. E., & Profitt, D. R. (1982). The minimum principle and the perception of absolute, common and relative motion. *Cognitive Psychology*, 14, 211-246.

De Groot, A. D. (1946). *Het denken van den schaker*. Amsterdam, Noord Hollandsche.

Deakin, J. M., & Allard, F. (1991). Skilled memory in expert figure skaters. *Memory and Cognition*, 19, 79-86.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: newborns prefer their mother's voices. *Science*, 208, 1174-1176.

de Groot, A. D. (1965). *Thought and choice in chess*. The Hague, Netherlands: Mouton (Original work published 1946).

DeGutis, J., Wilmer, J., Mercado, R. J., & Cohan, S. (2013). Using regression to measure holistic face processing reveals a strong link with face recognition ability. *Cognition*, 126 (1), 87-100.

Diaz, G., Fajen, B. R., & Phillips, F. (2012). Anticipation from biological motion: the goalkeeper problem. *Journal of Experimental Psychology: Human Perception and Performance*, 38 (4), 848-864.

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.

Didierjean, A., & Marmeche, E. (2005). Anticipatory representation of visual basketball scenes by novice and expert players. *Visual Cognition*, 12, 265-283.

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

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, Heidelberg: Springer-Verlag.

Duffy, T., & D. H. Jonassen (1991). *Instructional principles for constructivism learning environments*. Hillsdale, NJ; Lawrence Erlbaum.

Endsley, M.R., & Smith, R. P. (1996). Attention distribution and decision making in tactical air combat. *The Journal of Human Factors and Ergonomics Society*, 38 (2), 232-249.

Ericsson, K. A. (1996). The acquisition of expert performance: An introduction to some of these issues. In K. A. Ericsson (Eds.), *The Road to Excellence: The Acquisition of*

*Expert Performance in the Arts and Sciences, Sports and Games* (pp. 1-50). New York, NY: Lawrence Erlbaum Associates.

Ericsson, K. A. (2003). 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 and K. A. Ericsson (Eds.), *Expert performance in Sports: Advances in Research on Sport Expertise* (pp. 371-402). Champaign, IL: Human Kinetics.

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 and 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., 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 of maximal adaptation to task constraints. *Annual Review of Psychology,* 47, 273-305.

Ericsson, K. A., Nandagopal, K., & Roring, R. W. (2009). An expert performance approach to the study of giftedness. In Shavinina, L. V. (Eds), *International Handbook on Giftedness* (pp. 129-153). Netherlands: Springer.

Ericsson, K. A., Patel, V., & 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., & Smith, J. (1991). *Toward a General Theory of Expertise: Prospects and Limits*. Cambridge: Cambridge University Press.

Eriksen, C. W., & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & Psychophysics,* 40, 225-240.

Eriksen, C. W., & Yeh, Y. Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception & Performance*, 11, 583-597.

Farrow, D., & Abernethy, B. (2002). Can anticipatory skills be learned through implicit video based perceptual training? *Journal of Sports Sciences*, 20, 471-485.

Farrow, D., Chivers, P., Hardingham, C., & Sachse, S. (1998). The effect of video-based perceptual training on the tennis return of serve. *International Journal of Sport Psychology*, 29 (3), 231-242.

Farrow, D., McCrae, J., Gross, J., & Abernethy, B. (2010). Revisiting the relationship between pattern recall and anticipatory skill. *International Journal of Sport Psychology*, 41, 91 106.

Féry, Y-A., & Crognier, L. (2001). On the tactical significance of game situations in anticipating ball trajectories in tennis. *Research Quarterly for Exercise and Sport*, 72 (2), 143-149.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47 (6), 381-391.

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.

Franks, I. M., & Hanvey, T. (1997). Cues for goalkeepers: high-tech methods used to measure penalty shot response. *Soccer Journal*, (May-June), 30-38.

French, K. E., & Thomas, J. R. (1987). The relation of knowledge development to children's basketball performance. *Journal of Sport Psychology*, 9, 15-32.

Frey, P. W., & Adesman, P. (1976). Recall memory for visually presented chess positions. *Memory and Cognition*, 4, 541-547.

Galton F. (1869). *Heredity genius*. New York: Macmillian.

Gardner, J. J., & Sherman, A. (1995). Vision requirements in sport. In D. F. C. Loran and C. J. MacEwen (Eds.), *Sports Vision* (pp. 22-36). Oxford: Butterworth-Heinemann.

Garland, D. J., & Barry, J. R. (1991). Cognitive advantage in sport: The nature of perceptual structures. *The American Journal of Psychology*, 211-228.

Gauthier, I., & Tarr, M. J. (2002). Unraveling mechanisms for expert object recognition: bridging brain activity and behavior. *Journal of Experimental Psychology: Human Perception and Performance*, 28 (2), 431-446.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. In, P. Thaggard (Ed.). *Mind Readings* (pp. 127-156). Cambridge, MA: MIT Press.

Gibson, E. J. (1969). *Principles of perceptual learning and development*. New York: Appleton-Century Crofts.

Gibson, J.J. (1950). *Perception of the visual world*. London: Allen & Unwin.

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston: Houghton Mifflin.

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

Gills, B., Helsen, W., Catteeuw, P., & Wagemans, J. (2008). Offside decisions by expert assistant referees in association football: perception and recall of spatial positions in complex dynamic events. *Journal of Experimental Psychology: Applied*. 14 (1), 21-35.

Girden, E. (1992). ANOVA: Thousand Oaks: Sage Publications.

Gobet, F. (1997). Roles of pattern recognition and search in expert problem solving. *Thinking and Reasoning*, 3, 291-313.

Gobet, F. (1998). Expert memory: a comparison of four theories. *Cognition*, 66, 115-152.

Gobet, F. (2000). Some shortcomings of long-term working memory. *British Journal of Psychology*, 91, 551-570.

Gobet, F. & Simon, H. A. (1996a). Recall of random and distorted positions: Implications for theory of expertise. *Memory & Cognition*, 24, 493-503.

Gobet, F., & Simon, H. A. (1996b). Templates in chess memory: A mechanism for recalling several boards. *Cognitive Psychology*, 31, 1-40.

Gobet, F., & Simon, H. A. (2000). Five seconds or sixty? Presentation time in expert memory. *Cognitive Science*, 24 (4), 651-682.

Goldin, S. E. (1978). Effects of orienting tasks on recognition of chess positions. *American Journal of Psychology*, 91, 659-671.

Goldstone, R. L. (1998). Perceptual learning. *Annual Review of Psychology*, 49, 585–612.

Goldstone, R. L., Medin, D. L., & Gentner, D. (1991). Relational similarity and the non-independence of features in similarity judgments. *Cognitive Psychology*, 23, 222-262.

Good, T. L., & Brophy, J. E. (1990). *Educational Psychology. A Realistic Approach (4th ed.)*. Reading, MA; Addison Wesley Publishing Company.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neuroscience*, 15, 20-25.

Goodale, M. A., & Servos, P. (1996). Visual control of prehension. In H. N. Zelaznik (ed.), *Advances in Motor Learning* (pp. 87-121). Champaign IL: Human Kinetics.

Gorman, A. D., Abernethy, B., & Farrow, D. (2011). Investigating the anticipatory nature of pattern perception in sport. *Memory & Cognition*, 39 (5), 894-901.

Gorman, A. D., Abernethy, B., & Farrow, D. (2012). Classical pattern recall tests and the prospective nature of expert performance. *Quarterly Journal of Experimental Psychology, 65*, 1151–1160.

Gorman, A. D., Abernethy, B., & Farrow, D. (2013a). Is the relationship between pattern recall and decision-making influenced by anticipatory recall? *The Quarterly Journal of Experimental Psychology*, 66 (11), 2219-2236.

Gorman, A. D., Abernethy, B., & Farrow, D. (2013b). The expert advantage in dynamic pattern recall persists across both attended and unattended display elements. *Attention, Perception, & Psychophysics*, 75 (5), 835-844.

Gottsdanker, R., & Kent, K. (1978). Reaction time and probability on isolated trials. *Journal of Motor Behavior*, 10 (3), 233-238.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics.* New York: Wiley.

Gregory, R. L. (1970). *The intelligent eye*. New York: McGraw-Hill.

Grehaigne, J-F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationships in collective actions in soccer. *Journal of Sports Science*, 15 (2), 137 149.

Guise, J. M. (2007). Anticipating and responding to obstetric emergencies. *Best Practice and Research in Clinical Obstetrics and Gynaecology*, 21 (4), 625-638.

Hagemann, N., Strauss, B., & Cañal-Bruland, R. (2006). Training perceptual skill by orienting visual attention. *Journal of Sport and Exercise Psychology*, 28, 143-158.

Harle, S. K., & Vickers, J. N. (2001). Training quiet eye improves accuracy in the basketball free throw. *The Sport Psychologist*, 15, 289-305.

Harris, K. R., Tashman, L., Ward, P., Ericsson, K. A., Eccles, D. W., Williams, A. M., Ramrattan, J., & Lang, L. H. (2006). Planning, evaluation, and cognition: Exploring the structure and mechanisms of expert performance in a representative dynamic task. *Proceeding from the 28th Annual Conference of the Cognitive Science Society* (pp. 328 332). Mahwah, NJ: Erlbaum.

Hayes, S. J., Hodges, N. J., Scott, M. A., & Williams, A. M. (2005). The efficacy of demonstrations in teaching children an unfamiliar movement skill: the effects of object orientated actions and point-light demonstrations. *Journal of Sports Sciences*, 25 (5), 559-575.

Hazel, C. A. (1995). The efficacy of sports vision practice and its role in optometry. *Clinical and Experimental Optometry*, 78, 98-105.

Helsen, W., & Pauwels, J. M. (1993). The relationship between expertise and visual information processing in sport. In J. L. Starkes and F. Allard (eds) *Cognitive Issues in Motor Expertise* (pp. 109-134). Amsterdam: Elsevier Science.

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

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

Henderson. J. M. (2003). Human gaze control during real-world scene perception. *Trends in Cognitive Sciences*, 7 (11), 498-504.

Herman, E., & Retish, P. (1989). Vision therapy- hoax, hope or homilies? A physical education perspective. *Adapted Physical Activity Quarterly*, 6, 299-306.

Hill, H., & Pollick, F. E. (2000). Exaggerating temporal differences enhances recognition of individuals from point light displays. *Psychological Science*, 11, 223-228.

Hodges, N. J., & Starkes, J. L. (1996). Wrestling with the nature of expertise: A sport-specific test of Ericsson, Krampe and Tesch-Romer's (1993) theory of 'deliberate practice'. *International Journal of Sport Psychology*, 27, 400-424.

Hodges, N. J., Williams, A. M., Horn, R. R., & Breslin, G. (2007). What is modelled during observational learning? *Journal of Sports Sciences, 25*, 5, 531-545.

Holding, D. H. (1985). The Psychology of Chess Skill. Hillsdale, NJ: Erlbaum.

Hollingworth, A., & Henderson, J. M. (2000). Semantic informativeness mediates the detection of changes in natural scenes. *Visual Cognition*, 7 (1-3), 213-235.

Holyoak, K. J., & Koh, K. (1987). Surface and structural similarity in analogical transfer. *Memory and Cognition*, 15, 332-340.

Hopwood, M. J., Mann, D. L., Farrow, D., & Nielsen, T. (2011). Does visual-perceptual training augment the fielding performance of skilled cricketers? *International Journal of Sports Science & Coaching*, 6 (4), 523-535.

Horn, R. R., Williams, A. M., & Scott, M. A. (2002). Learning from demonstrations: The role of visual search during observational learning from video and point light models. *Journal of Sports Sciences*, 20, 253-269.

Howard, J. H., & Kerst, S. M. (1981). Memory and perception of cartographic information for familiar and unfamiliar environments. *Human Factors*, 23, 495–504.

Howe, M. J. A., Davidson, J. W., & Sloboda, J. A. (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences*, 21, 399-442.

Huys, R., Canal-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 (2), 158-171.

Huys, R., Smeeton, N. J., Hodges, N. J., Beek, P. J., & Williams, A. M. (2008). On the dynamic information underlying visual anticipation skill. *Perception & Psychophysics*, 70 (7), 1217-1234.

Imwold, C. H., & Hoffman, S. J. (1983). Visual recognition of a gymnastics skill by experienced and inexperienced instructors. *Research Quarterly for Exercise and Sport*, 54, 149-155.

Jackson, R. C., & Farrow, D. (2005). Implicit perceptual training: how, when, and why? *Human Movement Science*, 24 (3), 308-325.

Janelle, C. M., & Hillman, C. H. (2003). Expert performance in sport: Current perspectives and critical issues. In J. L. Starkes and K. A. Ericsson (Eds), *Expert Performance in Sports. Advances in Research on Sport Expertise* (pp. 19-49). Champaign, IL: Human Kinetics.

Janelle, C. M., Singer, R. N., & Williams, A. M. (1999). External distraction and attentional narrowing: visual search evidence. *Journal of Sport and Exercise Psychology*, 21, 70 91.

Jastorff, J., Kourtzi, Z., & Giese, M. A. (2006). Learning to discriminate complex movements: biological versus artificial trajectories. *Journal of Vision*, 6, 791-804.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics*, 14, 201-211.

Johansson, G. (1976). Spatio-temporal differentiation and integration in visual motion perception. *Psychological Research*, 38, 379-393.

Jones, C. M., & Miles, T. R. (1978). Use of advance cues in predicting the flight of a lawn tennis ball. *Journal of Human Movement Studies*, 4, 231-235.

Kirlik, A., Walker, N., Fisk, A. D., & Nagel, K. (1996). Supporting perception in the service of dynamic decision making. *Human Factors*, 38, 288-299.

Kourtzi, Z., & Nakayama, K. (2002). Distinct mechanisms for the representation of moving and static objects. *Visual Cognition*, 9 (1-2), 248-264.

Laurent, E., Ward, P., Williams, A. M., & Ripoll, H. (2006). Expertise in basketball modifies perceptual discrimination abilities, underlying cognitive processes, and visual behaviors. *Visual Cognition*, 13, 247-271.

Lee, T. D. (2012). Contextual interference: Generalizability and limitations. In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice*. New York, NY: Routledge.

Lee, T.D., Chamberlin, C.J., & Hodges, N.J. (2001). Practice. In R.N. Singer, H.A. Hausenblas, & C.M. Janelle (Eds.), *Handbook of Sport Psychology* ($2^{nd}$ ed., pp.115-143). New York: Wiley.

Le Runigo, C., Benguigui, N., & Bardy, B. G. (2005). Perception–action and expertise in interceptive actions. *Human Movement Science*, 24, 429–445.

Lintern, G., Shepard, D., Parker, D., Yates, K., & Nolan, M. (1989). Simulator design and instructional features for air-to-ground attack: A transfer study. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 31, 87-99.

Magill, R.A. (1998). Knowledge is more than we can talk about: Implicit learning in motor skill acquisition. *Research Quarterly for Exercise and Sport*, 69 (2), 104-110.

Magill, R. A., & Hall, K. G. (1990). A review of the contextual interference effect in motor skill acquisition. *Human Movement Science*, 9, 241–289.

Mann, D.T.Y., Ward, P., Williams, A.M., & Janelle, C.M. (2007). Perceptual cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology*, 29, 457 478.

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

McMorris, T., & Colenso, S. (1996). Anticipation of professional soccer goalkeepers when facing right-and-left footed penalty kicks. *Perceptual and Motor Skills*, 82 (3), 931 934.

Martell, S., & Vickers, J.N. (2004). Gaze characteristics of elite and near elite ice hockey players. *Human Movement Science.* 22, 689-712.

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

Masoura, E. V., & Gathercole, S. E. (1999). Phonological short-term memory and foreign language learning. *International Journal of Psychology*, 34 (5/6), 383-388.

Masters, R. S. W. (1992). Knowledge, knerves, and know-how: the role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British Journal of Psychology*, 83, 343-358.

Masters, R. S.W., & Maxwell, J. P. (2004). Implicit motor learning, reinvestment, and movement disruption: What you don't know won't hurt you? In A. M. Williams AM, & N. J. Hodges (Eds.). *Skill Acquisition in Sports: Research, Theory and Practice* (pp. 207–228). London, UK: Routledge.

Mather, G., & Murdoch, L. (1994). Gender discrimination in biological motion displays on dynamic cues. *Proceedings of the Royal Society of London*, 259, 273-279.

Mather, G., & West, S. (1993). Recognition of animal locomotion from dynamic point-light displays. *Perception*, 22, 759-766.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, 6 (6), 255-260.

McKenna, F. P., & Horswill, M. S. (1999). Hazard perception and its relevance for driver licensing. *Journal of International Association of Traffic and Safety Sciences*, 23, 36-41.

Mcleod, B. (1991). Effects of eyerobics visual skills training on selected performance measures of female varsity soccer players. *Perceptual and Motor Skills*, 24, 258-262.

McMorris, T., & Hauxwell, B. (1997). Improving anticipation of soccer goalkeepers using video observation. In T. Reilly, J. Bangsbo, and M. Hughes (Eds.), *Science and Football III (*pp. 290-294). London: E. & F.N. Spon.

McPherson, S. L., & Thomas, J. R. (1989). Relation of knowledge and performance in boys' tennis: Age and expertise. *Journal of Experimental Child Psychology*, 48, 190-211.

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.

Memmert, D. (2006). The effects of eye movements, age, and expertise on inattentional blindness. *Consciousness and Cognition*, 15, 620–627.

Memmert, D., & Furley, P. (2007). “I spy with my little eye!”: Breadth of attention, inattentional blindness, and tactical decision-making in team sports. *Journal of Sport and Exercise Psychology,* 29, 365-381.

Memmert, D., Hagemann, N., Althoetmar, R., Geppert, S., & Seiler, D. (2009). Conditions of practice perceptual skill learning. *Research Quarterly for Exercise and Sport*, 80 (1), 32-43.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limited on our capacity for processing information. *Psychological Review*, 63 (6), 81-97.

Milner, D. A., & Goodale, M. A. (1995). *The visual brain in action*. Oxford: Oxford University Press.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: a latent variable analysis. *Cognitive Psychology*, 41, 49 100.

Monsell, S. (1996). Control of mental processes. In V. Bruce (Eds), *Unsolved Mysteries of the Mind: Tutorial Essays in Cognition* (pp. 92-148). East Sussex, UK: Psychology Press Ltd.

Morris, N., & Jones, D. M. (1990). Memory updating in working memory: the role of central executive. *British Journal of Psychology,* 81 (2), 111-121.

Müller, S., Abernethy, B., & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *Quarterly Journal of Experimental Psychology*, 59 (12), 216-286.

Nadine, C. F., & Kundle, H. L. (1987). Using eye movements to study visual search and to improve tumour detection. *Radio Graphics,* 7 (6), 1241-1250.

Newell, K. M. (1986). Constraints on the development of co-ordination. In M. G. Wade and H. T. A. Whiting (Eds.), *Motor Development in Children: Aspects of Coordination and Control* (pp. 341-361). Amsterdam: Martin Nijhoff.

Newell, A., & Simon, H. A. (1972). *Human Problem Solving*. Englewood Cliffs, NJ: Prentice Hall.

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.

North, J. S., & Williams, A. M. (2007). The processes underpinning skilled recognition and anticipation in soccer. In P. Beek, W. Schollhorn and W. Verwey (Eds.), *Proceedings of European Workshop on Movement Science* (p. 42). Amsterdam, Netherlands.

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. J., 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.

Nougier, V., Stein, J. F., & Bonnel, A. M. (1991). Information processing in sport and orienting attention. *International Journal of Sport Psychology*, 22, 307-327.

Novick, L. R., & Sherman, S. J. (2003). On the nature of insight solutions: evidence from skill based differences in anagram solution. *The Quarterly Journal of Experimental Psychology*, 56 (A), 351-382.

Osborne, K., Rudrud, E., & Zezoney, F. (1990). Improved curveball hitting through the enhancement of visual cues. *Journal of Applied Behavior Analysis*, 23, 371-377.

Oslin, J. L., Mitchell, S. A., & Griffin, L. L. (1998). The game performance assessment instrument (GPAI): Development and preliminary validation. *Journal of Teaching Physical Education*, 17 (2), 231-243.

Paull, G., & Glencross, D. (1997). Expert perception and decision making in baseball. *International Journal of Sport Psychology*, 28, 35-56.

Pavlov, I. P. (1897/1902). *The work of the digestive glands*. London: Griffin.

Peterson, M. A., & Rhodes, G. (Eds).  (2003). *Perception of faces, objects, and scenes: analytic and holistic.* Oxford University Press: Oxford.

Piaget, J. (1985). *The equilibrium of cognitive structures: the central problem of intellectual development*. Chicago, IL; University Chicago Press.

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

Poizner, H., Bellugi, U., & Lutes-Driscoll, V. (1981). Perception of American sign language in dynamic point-light displays. *Journal of Experimental Psychology: Human Perception and Performance*, 7 (2), 430-40.

Posner, M. J. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3-25.

Poulter, D. R., Jackson, R. C., Wann, J. P., & Berry, D. C. (2005). The effect of learning condition on perceptual anticipation, awareness, and visual search. *Human Movement Science*, 24, 345-361.

Ranganathan, R., & Carlton, L. G. (2007). Perception-action coupling and anticipatory performance in baseball batting. *Journal of Motor Behavior*, 39, 369–380.

Rasmussen, J. (1985). The role of hierarchical knowledge representation in decision making and system management. *IEEE Transactions on Systems, Man and Cybernetics,* 15, 234-243.

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences,* 18, 695-702.

Richler, J. J., & Gauthier, I. (2014). A meta-analysis and review of holistic face processing. *Psychological Bulletin*, 140 (5), 1281-1302.

Ripoll, H. (1988). Analysis of visual scanning patterns of volleyball players in a problem solvingtask. *International Journal of Sport Psychology*, 19, 9-25.

Ripoll, H. (1991). The understanding-acting process in sport: The relationship between the semantic and the sensorimotor visual function. *International Journal of Sport Psychology*, 22, 221-243.

Ripoll, H., Petit, J. P., & Le Troter, A. (2005). The relevance of using realistic simulated environments for the study of decision making in sport. In T. Morris, P. Terry, S. Gordon, S. Hanrahan, L. Ievleva, G. Kolt and P. Tremayne (Eds.), *Proceedings of 11th ISSP World Congress of Sport Psychology*. International Society of Sport Psychology: Sydney.

Roca, A., Ford, P. M., 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. M., McRobert, A. P., & Williams, A. M. (2013). Perceptual-cognitive skills and their interaction as a function of task constraints in soccer. *Journal of Sport & Exercise Psychology*, 35, 144-155.

Rowe, R. M., & Mckenna, F. P. (2001). Skilled anticipation in real-world tasks: measurement of attentional demands in the domain of tennis. *Journal of Experimental Psychology: Applied*, 7 (1), 60-67.

Royer, J., Blais, C., Frederic, G., Duncan, J., & Fiset, D. (2015). When less is more: impact of face processing ability on recognition of visually degraded faces. *Journal of Experimental Psychology: Human Perception and Performance*, 41 (5), 1179-1183.

Ryu, D., Abernethy, B., Mann, D. L., & Poolton, J. M. (2015). The contributions of central and peripheral vision to expertise in basketball: How blur helps to provide a clearer picture. *Journal of Experimental Psychology: Human Performance and Perception*, 41, 167-185.

Ryu, D., Kim, S., Abernethy, B., & Mann, D. L. (2013). Guiding attention aids the acquisition of anticipatory skill in novice soccer goalkeepers. *Research Quarterly for Exercise and Sport*, 84 (2), 252-262.

Russo, M.B., Kendall, A.P., Johnson, D.E., Sing, H.C., Thorne, D.R., Escolas, S.M., et al. (2005). Visual perception, psychomotor performance, and complex motor performance during an overnight air refuelling simulated flight. *Aviation, Space, and Environmental Medicine*, 76 (7 Suppl), C92-103.

Saariluoma, P. (1984). *Coding problem spaces in chess: a psychological study*. Commentationes scientiarum socialium 23. Turku: Societas Scientiarum Fennica.

Salmela, J. H., & Fiorito, P. (1979). Visual cues in ice-hockey goaltending. *Canadian Journal of Applied Sport Science*, 4, 56-59.

Savelsbergh, G. J. P., van Gastel, P. J., & van Kampen, P. M. (2010). Anticipation of penalty kicking direction can be improved by directing attention through perceptual learning. *International Journal of Sport Psychology*, 41, 24-41.

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.

Scully, D. M., & Carnegie, E. (1998). Observational learning in motor skills acquisition: A look at demonstrations. *The Irish Journal of Psychology*, 19, 472-485.

Shim, J., Carlton, L. G., & Kim, J. (2004). Estimation of lifted weight and produced effort through perception of point-light display. *Perception*, 33, 277-291.

Shuell, T. J. (1986). Cognitive conceptions of learning. *Review of Educational Research*, 56 (4), 411-436.

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 Sports Psychology*, 8, 9-26.

Skinner, B. F. (1938). *The behaviour of organisms*. New York: Appleton-Century.

Slater, A., & Morison, V. (1985). Shape constancy and slant perception at birth. *Perception*, 14, 337-344.

Smeeton, N., Ward, P., & Williams, A. M. (2004). Transfer of perceptual skill in sport. *Journal of Sports Science*, 19, 3-9.

Smeeton, N. J., Williams, A. M., Hodges, N. J., & Ward, P. (2005). The relative effectiveness of various instructional approaches in developing anticipation skill. *Journal of Experimental Psychology: Applied*, 11, 98-110.

Sowden, P. T., Davies, I.R.L., & Roling, P. (2000). Perceptual learning of the detection of features in X-ray images: A functional role for improvements in adults' visual sensitivity? *Journal of Experimental Psychology: Human Perception and Performance*, 26 (1), 379-390.

Starkes, J. L (1987). Skill in Field Hockey: The Nature of the Cognitive Advantage. *Journal of Sport Psychology*, 9, 146-160.

Starkes, J. L. (1993). Motor experts: opening thoughts. In J. L. Starkes and F. Allard (Eds.), *Cognitive Issues in Motor Expertise* (pp. 3-16). Amsterdam: Elsevier.

Starkes, J. L., & Allard, F. (Eds.) (1993). *Cognitive issues in motor expertise*. Amsterdam: Elsevier Science Publishing.

Starkes, J., Allard, F., Lindley, S., & O'Reilly, K. (1994). Abilities and skill in basketball. *International Journal of Sport Psychology*, 25 (3), 249-265.

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

Stavredes, T. (2011). *Effective online teaching: Foundations and strategies for student success*. San Fransico; Jossey-Bass.

Stine, C. D., Arterbrun, M. R., & Stern, N. S. (1982). Vision and sports: A review of the literature. *Journal of the American Optometric Association*, 53, 627-633.

Svartdal, F. (1989). Shaping of rule-governed behaviour. *Scandinavian Journal of Psychology*, 30 (4), 304-314.

Svartdal, F. (1992). Sensitivity to nonverbal operant contingencies: do limited processing resources affect operant conditioning in humans? *Learning and Motivation*, 23 (4), 383 405.

Sweller, J. (1988). Cognitive load during problem solving: effects on learning. *Cognitive Science*, 12, 257-285.

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.

Travassos, B., Araujo, D., Davids, K., O'Hara, K., Leitao, J., & Cortinhas, A. (2013). Expertise effects on decision-making in sport are constrained by requisite response behaviours - a meta-analysis. *Psychology of Sport and Exercise*, 14, 211–219.

Triolet, C., Benguigui, N., Le Runigo, C., & Williams, A. M. (2013). Quantifying the nature of anticipation in professional tennis. *Journal of Sports Science*, 31 (8), 820 830.

Tyldesley, D. A., Bootsma, R. J., & Bomhoff, G. T. (1982). Skill level and eye movement patterns in a sport oriented reaction time task. In H Rieder, H Mechling and K Reischle (Eds.), *Proceedings of an International Symposium on Motor Behaviour: Contribution to Learning in Sport* (pp. 290-296). Cologne: Hofmann.

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 and Exercise Psychology*, 29 (2), 156-175.

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L., & Philippaerts, R. M. (2007b). Visual search behaviour and decision-making skill in soccer. *Journal of Motor Behavior*, 39 (5), 395-408.

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

Vicente, K. J., & Wang, J. H. (1998). An ecological theory of expertise effects in memory recall. *Psychological Review*, 105 (1), 33-57.

Vickers, J., & Williams, A. M. (2007). Why some choke and others don't! *Journal of Motor Behavior,* 39 (5), 381-394.

Vine, S. J., Moore, L. J., & Wilson, M. R. (2014). Quiet eye training: the acquisition, refinement and resilient performance of targeting skills. *European Journal of Sport Science*, 14 (1), S235-S242.

Vygtsky, L. (1978). Interaction between learning and development. In M. Gauvain and M. Cole (Eds), *Readings on the Development of Children* (pp. 79-91). Cambridge, MA; Harvard University Press.

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

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., & Williams, A. M. (2003). Perceptual and cognitive skill development in soccer: the multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology, 25* (1), 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., & Loran, D. F. C. (2000). The development of visual function in elite and sub-elite soccer players. *International Journal of Sports Vision*, 6, 1-11.

Weber, N., & Brewer, N. (2003). Expert memory: The interaction of stimulus structure, attention, and expertise. *Applied Cognitive Psychology*, 17, 295-308.

Werner, S., & Thies, B. (2000). Is "Change blindness" attenuated by domain-specific expertise? An expert-novices comparison of change detection in football images. *Visual Cognition*, 7, 163-173.

West, K. L., & Bressan, E. S. (1996). The effects of general versus specific visual cues training program on accuracy in judging length-of-ball in cricket. *International Journal of Sports Vision*, 3, 41-45.

Wilkinson, S. (1992). Effects of training in visual discrimination after one year: Visual analyses of volleyball skills. *Perceptual and Motor Skills*, 75, 19-24.

Williams, A. M. (2002). Visual search behaviour in sport. *Journal of Sports Sciences*, 20, 169 170.

Williams, A.M. (2009). Perceiving the intentions of others: how do skilled performers make anticipation judgments? *Progress in Brain Research*, 174, 73-83.

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

Williams, A. M., & Davids, K. (1995). Declarative knowledge in sport: a byproduct of experience or characteristic of expertise? *Journal of Sport and Exercise Psychology*, 17, 259-275.

Williams, A. M., & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly for Exercise and Sport*, 69 (2), 111-128.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1992). Perception and action in sport. *Journal of Human Movement Studies*, 22, 147-204.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1993). Cognitive knowledge and soccer performance. *Perceptual and Motor Skills*, 76, 579-593.

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: E. & F.N. Spon.

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

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

Williams, A. M., Ericsson, K.A., Eccles, D., & Ward, P. (2008). Research on expertise in sport: Implications for the military. *Military Psychology*, S1-23.

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. (2013). 'Game intelligence': Anticipation and decision making. In A. M. Williams (Ed.), *Science and Soccer: Developing Elite Performers* (3rd ed.) (pp. 105-121). London: Routledge.

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport. *International Review of Sport and Exercise Psychology*, 25, 432-442.

Williams, A. M., & Franks, A. (1998). Talent identification in soccer. *Sports Exercise and Injury*, 4, 159-165.

Williams, A. M., & Grant, A. (1999). Training perceptual skill in sport. *International Journal of Sport Psychology*, 30, 194–220.

Williams, A. M., Heron, K., Ward, P., & Smeeton, N. J. (2004). Using situational probabilities to train perceptual and cognitive skill in novice soccer players. *Journal of Sports Sciences*, 22, 575-576.

Williams, A. M., & Hodges, N. J. (2005). Practice, instruction and skill acquisition in soccer: Challenging tradition. *Journal of Sports Sciences*, 23, 637-650.

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

Williams, A. M., & North, J. S. (2009). Identifying the minimal essential information underlying pattern recognition. In D. Arajuo, H. Ripoll, & M. Raab (Eds.) *Perspectives on Cognition and Action* (pp. 95-107). Nova Science Publishing.

Williams, A. M., North, J. N., & Hope, E. R. (2012). Identifying the mechanisms underpinning recognition of structured sequences of action. *Quarterly Journal of Experimental Psychology*, 65, 1975–1992.

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

Williams, A. M., & Ward, P. (2002). Developing perceptual expertise in sport. In A. Ericsson and J. Starkes (Eds.) *Expertise in Sport*. Champaign, IL: Human Kinetics.

Williams, A. M., & Ward, P. (2003). Perceptual expertise: Development in sport. In J. L. Starkes and K. A. Ericsson (Eds.), *Expert Performance in Sports: Advances in Research on Sport Expertise,* (pp.220-249). Champaign, IL: Human Kinetics.

Williams, A. M., & Ward, P. (2007). Perceptual-cognitive expertise in sport: Exploring new horizons. In G. Tenenbaum and R. Eklund (Eds.), *Handbook of Sport Psychology* (3rd ed.) (pp.203-223). New York: John Wiley & Sons.

Williams, A. M., Ward, P., & Chapman, C. (2003). Training perceptual skill in field hockey: is there transfer from the laboratory to the field? *Research Quarterly for Exercise and Sport*, 74, 98–103.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. J. (2002). Anticipation skill in a real-world task: Measurement, training and transfer in tennis. *Journal of Experimental Psychology: Applied*, 8, 259–270.

Williams, A. M., Ward, P., & Smeeton, N. J. (2004). Perceptual and cognitive expertise in sport: implications for skill acquisition and performance enhancement. In A. M. Williams and N. J. Hodges (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 328 348). London: Routledge.

Williams, A. M., Ward, P., Smeeton, N. J., & Allen, D. (2004). Developing anticipation skills in tennis using on-court instruction: perception versus perception and action. *Journal of Applied Sport Psychology*, 16, 350–360.

Wilson, T. A., & Falkel, J. (Ed.) (2004). *SportsVision: Training for better performance*. Champaign, IL: Human Kinetics.

Wong, W., & Rogers, E. S. (2007). Recognition of temporal patterns: fromengineering to psychology and back again. *Canadian Journal of Experimental Psychology*, 61, 159-167.

Wood, J. M., & Abernethy, B. (1997). An assessment of the efficacy of sports vision training programs. *Optometry and Vision Science*, 74 (8), 646-65.