Identifying the Minimal Essential Information Underpinning Skilled Anticipation in Soccer

Jamie North

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Contents

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Abstract

A series of experiments are presented that combined together attempted to identify essential information underpinning skilled recognition and anticipation in soccer. First participants made anticipation decisions to film sequences before completing an incidental recognition task to film and point-light display sequences. Eye movement behaviours were recorded throughout. Skilled soccer players' superior recognition performance was maintained across film and point-light formats, and displayed eye movement behaviours consistent with processing relational information. Eye movement behaviours suggested the central attacking players were important to skilled players' decision-making. Eye movement behaviours also suggested that different processes dictated recognition and anticipation. Next, the same experimental design was used only retrospective verbal reports were collected after anticipation and recognition tasks instead of eye movement behaviours. Skilled players superior recognition across display formats was replicated. During decision-making skilled players engaged more complex representations characterised by reference to more varied stimuli and action statements, and more task-relevant evaluations. Evidence was again presented that different processes govern recognition and anticipation. Central attacking players again conveyed important information. A third experiment using a temporally occluded recognition paradigm provided evidence that in soccer structure emerges as isolated incidents in the 3-seconds preceding an attacking event. A final experiment compared recognition of static and dynamic displays. Evidence is provided that skilled players perceive structure as relative motion information. Together the findings imply that skilled players recognise scenarios as a function of relational information. Specifically this is conveyed through relative motion between features, and emerges in the final moments preceding an attacking event. Finally, the central attacking players are the most important display features to convey this information. Findings are discussed in relation to encoding specificity principle, interactive encoding model, long term working memory, proactive interference, and the expert performance approach. The findings have important implications for sports coaches and other practitioners within the applied domain.

Chapter 1

Expertise: The Role of Perceptual-Cognitive Skill

A background to research into expertise

The majority of individuals aspire to achieve excellence, even expertise, within their chosen field be it music, mathematics, surgery or sport. Whatever the domain, the achievement of expertise is something to behold and marvel. However, those who achieve expert status in the sporting field find themselves under the spotlight and open to scrutiny given the mass global popularity of sport. Spectators, coaches, competitors and team-mates, the media, and scientists are united in their interest and appreciation of expert sport performance in action. The popularity of The Olympic Games, FIFA World Cup, Super Bowl, Wimbledon, and many other events only serve to emphasise the appeal of expert performance in action (Janelle & Hillman, 1993).

Although sport has mass appeal globally, only a few select individuals reach the elite level whilst the majority fall by the wayside. A key question therefore is what sets expert performers apart from the crowd and enables them to achieve their level of performance? This question has stimulated much scientific research and has important theoretical connotations. Research on expertise helps identify the constructs that potentially predispose individuals to excellence, and the processes that are engaged in during expert behaviours. Secondly, it also contributes to the nature vs. nature debate that has long raged in psychological literature regarding every imaginable human condition (e.g., depression, Kassem, Lopez, Hadeker, Steele, Zandi, & McMahon, 2006; schizophrenia, Jablensky, 2006) by considering whether such factors are innate or developed through practice. Expertise research has now become an established domain of study in the sport and exercise sciences as well as in cognitive psychology as evidenced by the growing body of literature (e.g., Arroyo-Figueroa, Hernandez, & Sucar, 2006;

Ericsson, 1996; Starkes & Ericsson, 2003; Williams & Ericsson, 2005; Williams & Starkes, 2002). Another population who have a keen interest in identifying the factors that predispose one to attaining expertise are sports practitioners working in the applied domain. At the elite level there is immense pressure for teams to attain and retain the services of the most talented individuals. Although some sporting teams have the luxury of being able to outlay large sums of money to achieve this aim, others do not have such financial support. In such scenarios the pressure involved when attempting to identify and nurture talent is magnified and therefore any objective measures uncovered through scientific practice that indicate a propensity to expertise have great potential to supplement existing scouting procedures (Williams & Reilly, 2000).

In attempting to explain and account for expertise, theorists have historically fallen into one of two contrasting schools of thought favouring either a genetic, innate viewpoint (nature) or alternatively stressing the influence of practice and experience (nurture). Initially, scientists believed that such behaviour was determined solely through inherited genetic factors immune to training and practice (see Galton, 1869). Similarly, in the motor skills literature a general motor ability hypothesis (Brace, 1927; McCloy, 1934) existed whereby a unitary genetically defined ability was presumed to exist which predisposed an individual to success in any motor skill. However, disappointingly for proponents of such views, there is little empirical support for their claims (e.g., see Drowatzky & Zuccato, 1967; Lotter, 1960). Similarly, it was proposed that chess experts' and music experts' skills were determined by an inherited intellectual capacity, although here again there is no evidence to support this view (Shuter-Dyson & Gabriel, 1981). Finally, in a motor learning context, the overwhelming evidence contradicts the notion of a genetic motor ability underpinning skill acquisition as research reported very low correlations between participants' performance across simple motor tasks, even those that were seemingly similar (see Drowatsky & Zuccato, 1967; Zelaznik, Spencer, & Doffin, 2000).

At the opposing end of the continuum is the proposal that expertise is not governed by genetics, but is a consequence of extended practice within a specific domain. In order to attain expert status some researchers have argued that 10 years or 10,000 hours of deliberate practice is required (Ericsson, Krampe, & Tesch-Romer, 1993). Exposure alone is not sufficient, but rather certain conditions must be met to satisfy the term 'deliberate practice'. Ericsson et al. (1993) outlined three critical constraints. Early investment in practice should not be financially rewarding for the performer, and may involve expenditure to acquire the appropriate resources. Second, practice should be physically and mentally demanding to the performer. Finally, practice is assumed to not be enjoyable. The desire to improve motivates the performer to sustain their participation. If these constraints are satisfied and combined with clearly defined activities that are set at an appropriate level of difficulty, where there is opportunity for repetition, and feedback and error detection/correction is provided then the optimal environment is provided to enable deliberate practice. The principle behind such a stance is that expertise is achievable by anyone provided they accumulate sufficient amounts of deliberate practice. A less extreme 'nurturist' perspective highlights the vital and necessary role of deliberate practice in attaining expertise, however also acknowledges that certain hereditary factors such as ability or motivation may limit the level of skill that is attainable. Such a view may be termed an 'interactionist' perspective. Regardless, without years of deliberate practice the attainment of expertise may not be achieved.

With the exception of some basic physical characteristics such as height, almost all elements of the body as well as human behaviour are adaptive to environmental demands (Ericsson, 2003). Ericsson and Lehmann (1996) cite examples of perceptual, cognitive, and motor capacities that have been acquired through practice (see, Gibson, 1969; Keele & Ivry, 1987; Schlaug, Jancke, Huang, & Steinmetz, 1995). Given the evidence for these adaptations, and the excessive practice engaged upon en-route to expertise, it is likely that expert performers will demonstrate a unique set of characteristics that differentiate them from less-skilled individuals. Certainly expertise is highly complex and in the study of expert sports performers alone research has identified expertise on the basis of anthropometrical (Borms, 1996), physiological (Wilmore & Costill, 1999), psychological (Abbott & Collins, 2004), cognitive (Jackson & Farrow, 2005), and sociological (Côté, 1999) factors amongst others.

Characteristics of success in soccer and other similar domains

Early researchers focusing on expertise in the sporting domain were limited by the application of theoretical constructs and paradigms direct from mainstream psychology, with little or no thought given to the unique constraints defining expertise in the sporting environment (Abernethy, Thomas, & Thomas, 1993). It was assumed that paradigms that had been successfully applied to studying expert performance in domains such as bridge and chess would be equally appropriate for the study of expertise in mainstream sport. However, every performance domain is likely to be governed by unique performance constraints (see Vicente & Wang, 1998) and these must be acknowledged in developing appropriate research methodologies. The expert sports performer must make complex, temporally constrained responses in a dynamic environment, often involving the interaction of numerous elements (Starkes, Helsen, & Jack, 2001; Williams & Ericsson, 2005). Furthermore, success in the sporting domain is often determined by the quality and execution of the movement response, which is not the case in domains such as bridge and chess (Starkes et al., 2001). There is also evidence that the specific requirements and demands will vary between sports (Cockerill, 1981; Hoare & Warr, 2000) and also within sports from one position to another (Williams, Davids, & Williams, 1999).

Dynamic team ball sports are especially complex in nature with evidence of multi-factorial contributory factors to expert performance (see Hugg, 1994; Reilly, Williams, Nevill, & Franks, 2000; Williams & Franks, 1998). Researchers have identified a number of anthropometric, physical, and physiological characteristics such as somatotype (Pena Reyes, Cardenas-Barahona, & Malina, 1994) and anaerobic power (Jankovic, Matkovic, & Matkovic, 1997) that contribute to skilled performance in team sports such as soccer and basketball. Although these measures may reliably differentiate elite from less-skilled performers, as an individual progresses through the ranks in their sporting domain the peer population becomes increasingly homogenous with respect to these measures. Thus, whilst such measures may be useful to discriminate skilled and less-skilled populations, they may be less sensitive in differentiating within the skilled population (Williams & Reilly, 2000). Within a skilled group it is proposed that other factors, specifically perceptual-cognitive skills such as anticipation, decision-making, recognition, and recall, are better determinants of those who will attain expertise in the domain (Williams & Reilly, 2000). Furthermore, Hoare and Warr (2000) argue that in team sports, anthropometric and physiological factors may be less important compared to psychological tactical factors that enable players to demonstrate 'game knowledge'. In support of these proposals Vaeyens, Lenoir, Williams, Mazyn, and Phillipaerts (in press) report that a skilled population can be discriminated on decision-making skill using such perceptual cognitive indices as eye movement data.

Given the temporally demanding nature of sports competition a vital characteristic of expert sports performance is the ability to anticipate the actions of an opponent or opposing team (Abernethy, 1987). The batsman preparing to face a fast bowler in cricket, the tennis player returning serve, and the soccer defender attempting to identify an opposing team's developing attack provide examples of the importance of anticipation skill in sport. In line with the 'nature' argument advocated by Galton (1869) is the view that expert sports performers are blessed with superior visual 'hardware' (e.g., Blundell, 1984, 1985; Sanderson, 1981). In essence a superior visual system allows them to 'see better' and process more information at a faster rate, consequently facilitating effective anticipation (for a detailed review, see Williams et al., 1999). Although intuitively appealing, the available evidence does not support such a proposal. Using batteries of optometric tests, researchers have been unable to distinguish between skilled and less-skilled soccer players (see Helsen & Starkes, 1999; Ward & Williams, 2003; Ward, Williams, & Loran, 2000). In addition, despite considerable evidence that basic visual functions can be improved through specialised training programmes (e.g., eyerobics, Revien, 1987) there is no evidence to support the proposition that these improvements transfer to the sports field (West & Bressan, 1996; Wood & Abernethy, 1997).

In the absence of evidence supporting the 'hardware' hypothesis, attention shifted to whether the anticipation skill governing expert performance may be influenced by perceptual-cognitive knowledge structures developed as a function of experience (e.g., Anderson, 1987). As a function of a performer's experience within a domain they amass a greater task specific cognitive knowledge base that governs their characteristic perceptual expertise (Williams & Grant, 1999). The variable of active practice is critical to the process and supersedes any developments that may occur as a function of mere observation (Williams & Davids, 1995) or maturation (Abernethy, 1988). The acquired nature of expert performance and anticipation is said to represent the 'perceptual software' of a performer (Williams et al, 1999). The terms 'hardware' and 'software' were first coined by Starkes (1979) in her paper investigating the nature of the cognitive advantage in sport.

This body of research provides strong evidence in demonstrating that expert performance is governed by acquired perceptual-cognitive skills (for reviews, see Williams & Starkes, 2002; Williams & Ward, in press; Williams et al., 1999). This superior cognitive knowledge enables expert sports' performers to extract the most meaningful information from a display, and store and index this information effectively in memory. Once stored and indexed in memory the information can then be efficiently retrieved to facilitate performance in similar scenarios (Williams & Davids, 1998). This expert knowledge manifests itself in a variety of perceptual-cognitive tasks. For example, when compared with their less expert counterparts, expert athletes demonstrate a broader knowledge of playing patterns as indicated by superior recall and recognition skill (e.g., Williams, Hodges, North, & Barton, 2006); a superior ability to detect and utilise advance visual cues within a display (Abernethy, 1987); an enhanced ability to locate critical aspects such as the ball from background distracters (Allard & Starkes, 1980); adopt more efficient and effective visual search strategies (Williams, Davids, Burwitz, & Williams, 1994); and assign and rank a variety of situational probabilities (Ward & Williams, 2001). These distinguishing characteristics are domain specific rather than general (Abernethy, Neal, & Koning, 1994; Helsen & Starkes, 1999). For example, Allard and Starkes (1992) reported an interaction between sport played and sport to be recognised with expert ice hockey and basketball players demonstrating high response accuracy for stimuli that represented their domain of expertise, whereas recognition performance was significantly reduced when making recognition judgments to sequences showing the other sport. This highlights further the role of domain specific deliberate practice rather than any superior capacity enabling skilled performance across domains.

Assessing expertise and challenges facing the researcher

A performer's knowledge of patterns between features within their domain of expertise has been shown to be a defining attribute of expert performance in a variety of non-sporting domains such as chess (e.g., Chase & Simon, 1973), medical diagnosis (e.g., Patel, Groen, & Arocha, 1990), and computer programming (e.g., Barfield, 1986). In sport, a performer's 'game knowledge' or ability to 'read the game' is thought to symbolise their awareness of such patterns and be equally significant in contributing to expertise in the domain (Abernethy, Baker, & Cote, 2005).

The challenge facing researchers investigating expert performance is to devise laboratory tasks that equally capture the demands of the environment where the expert skills have been demonstrated in the first place (Ericsson & Smith, 1991; Williams & Ericsson, 2005). For skills such as typing, juggling, and weight lifting the conditions are easily replicated in a laboratory environment. However, the investigator is faced with a far greater challenge when it comes to devising an experimental laboratory task that will accurately capture the demands placed upon the performer when anticipating future actions of opponents or opposing teams. Such a task is critical to the scientific study of expertise, as methods that only represent sporting competition in an abstract manner have sometimes found no difference in performance across athletes of varying degrees of skill (see, Tenenbaum & Bar-Eli, 1993; Ward & Williams, 2003).

The seminal work in the scientific study of expertise was conducted by de Groot (1946/1978) who examined expert performers' perception and prediction of forthcoming chess moves whilst monitoring their thought processes. The expert players accessed the best moves as predicted. Critically, however, the thought processes indicated that these selections were accessed during the performer's initial perception rather than after an extensive search. Such a finding suggested that performance was mediated by pattern-based retrieval from memory. In subsequent research assessing performers' cognitive knowledge and awareness of such patterns two methodological paradigms have been popularly used, namely the recall and recognition paradigms.

In the recall paradigm participants are presented with stimuli representing sequences of play and are later asked to recall the positions of the features shown. In the recognition paradigm participants are shown a number of sequences, some which have been presented during an earlier viewing phase and some that are novel. For each stimulus, participants are required to make a familiarity judgement as to whether it was presented previously or not. The accuracy of participants' recall of positions or recognition of sequences is taken as a measure of performance to indicate skill.

Chase and Simon (1973) demonstrated that when expert chess players were presented with stimuli showing real game positions they were more accurate in recalling these sequences compared to less-skilled players. Chase and Simon (1973) also showed that this expert advantage disappeared when performers were asked to recall stimuli that showed boards with chess pieces randomly organised. The introduction of this 'control condition' was vital in demonstrating that expert performance was not a consequence of any innate superior intellect or memory ability, and confirmed that performance was a consequence of domain specific memory and cognitive knowledge developed as a function of practice. Chess was also the domain studied when the recognition paradigm was first applied to the study of expertise (Charness, 1976; Goldin, 1978, 1979). The findings replicated those reported using the recall paradigm, namely that expert players recognition accuracy was superior to less-skilled counterparts, and this advantage was restricted to 'structured' sequences only. This expert knowledge is a direct function of prolonged deliberate practice and a characteristic of expertise, not a by-product of simple experience or exposure through merely watching a sport (Allard, Deakin, Parker, & Rodgers, 1993; Williams & Davids, 1995). Helsen, Stakes and Hodges (1998) were the first to investigate the contribution of deliberate practice to elite skill in the domain of soccer. Using a sample of provincial, national, and international soccer players, Helsen et al. (1998) reported that the amount of deliberate practice engaged in was a critical factor in distinguishing between skill levels. The data also produced some interesting results, suggesting that in soccer deliberate team practice may be more important than deliberate practice alone, and also that the amount of deliberate practice hours accumulated may be less than the 10,000 originally proposed (see Ericsson et al., 1993). Although the work of Helsen et al. (1998) raised important considerations regarding whether the principles outlined in deliberate practice theory may be somewhat task dependent, it nevertheless did demonstrate the important role of deliberate practice in achieving elite levels of performance. Addressing the issue of experience, Williams and Davids (1995) examined recall of soccer players matched for experience, but differentiated upon skill level and the type of practice engaged in, and also a group of disabled supporters who had extensive soccer viewing experience. The skilled group demonstrated superior recall performance on 'structured' trials only suggesting that this knowledge is a direct component of soccer skill and not a by-product occurring through repeated exposure. The disabled group demonstrated the least accurate recall performance suggesting that actively engaging in the sport is important to promote the retention of domain specific knowledge.

Scientists interested in the study of expert sport performance subsequently applied these recall and recognition paradigms to their specific domain of interest. Allard, Graham, and Paarsalu (1980) tested skilled and less-skilled basketball players using both recall and recognition paradigms. Structured slides represented actual match scenes, whereas unstructured slides showed players warming up, or during breaks in play. Allard et al. (1980) reported that skilled basketball players were more accurate than less-skilled players at recalling and recognising structured stimuli, with no differences on the unstructured slides. This pattern of results was subsequently replicated across a variety of sporting domains including American football (Garland & Barry, 1991), gymnastics (Imwold & Hoffman, 1983), figure skating (Deakin & Allard, 1991), and snooker (Abernethy, Neal, & Koning, 1994). Based upon the available evidence it is believed that expert performers encode the most meaningful information to a deeper more conceptual level facilitating ease of subsequent retrieval thus accounting for their recognition of attacking patterns (Ericsson & Kintsch, 1995; Ericsson, Patel, & Kintsch, 2000). From a practical perspective it is proposed that expert anticipation is underpinned by this recognition of previously encountered patterns and evaluation of the likely outcome.

The use of these imported methodological paradigms was criticised for the failure of researchers to modify the research design in acknowledgement of the unique characteristics of the sporting context (Starkes, Helsen, & Jack, 2001). Of particular criticism was the use of static displays, which may be appropriate for the study of activities such as chess and bridge, but given the dynamic nature of sport it is plausible that motion may be a critical component of the recognition and perception process (Dittrich, 1999; Dittrich & Lea, 1999; Johansson, 1973, 1975). In support of this potentially limiting methodological factor, Borgeaud and Abernethy (1987) reported that the expert advantage in relation to superior recall performance only emerged when static displays were substituted for dynamic stimuli in volleyball. This concern was also addressed by Williams and Davids

(1995) who recorded response time as well as accuracy to capture the temporally constrained nature of most sporting competition, and also ensured the display presented to participants accurately reflected the perspective they would typically encounter in a competitive real-life environment. Such modifications reflect the importance of the researcher to ensure that test conditions mirror the performance environment as accurately as possible in order that the attributes characterising expert performance are captured (Ericsson & Smith, 1991; Williams & Ericsson, 2005).

Despite the body of evidence supporting the use of these tools, and methodological modifications made to ensure testing captures the features of the performance environment, some researchers still contend that the recall and recognition paradigms are not appropriate to study expert performance. Ericsson and Lehmann (1996) argue that such tasks are not sufficiently representative of the complex perceptual-cognitive processes performers engage in when making actual anticipation decisions. Consequently, while recognition performance may capture a related function, it is one that is not directly engaged during the anticipation process. Therefore, Ericsson and Lehmann (1996) propose that although research has demonstrated a relatively consistent skill advantage on such tasks it is due to the tasks measuring a by-product of domain exposure rather than actually capturing anticipation skill. Alternatively to support the proposal that such paradigms accurately capture functions that are important constituents of expertise, Williams and Davids (1995) constructed a measure of anticipation skill and later measured participants' recall and recognition performance. Both measures were reported to be predictive of anticipation. Abernethy et al. (2005) also comment that "it is now well established that superior recall and recognition of domain specific patterns is a defining attribute of the expert sports performer" (p. 706).

Although recognition and recall are used as tests of expert memory and both have been reported to be important components of anticipation, some evidence suggests each skill demands different cognitive processes. A seemingly robust interaction is observed between type of test and stimuli frequency/familiarity. Participants have demonstrated superior memory recall for high frequency words (see Ward, Woodward, Stinson, & Stevens, 2003), yet when asked to recognise the same class of stimuli the trend is reversed such that superior performance is evidenced on low frequency words (see Guttentag & Carroll, 1997). The findings are replicated in recall and recognition of pictures also (see Karlson and Snodgrass, 2004). It is proposed that less familiar information encoded and stored in memory has fewer associated retrieval cues, such that when a cue is presented it appears more distinctive than other highly familiar items that have many associated and thus interfering retrieval cues. However, by their nature the high frequency stimuli are accessed more frequently, thus enabling retrieval in the absence of any retrieval cues. Such an account is consistent with the Search of Associative Memory Model (Gillund & Shiffrin, 1984). Thus it may be the case that recall and recognition operate as autonomous skills each making separate contributions to expert performance.

Theories of expert performance

To account for their findings regarding expert chess performance, Chase and Simon (1973) produced the first theory of expertise. Their 'chunking theory, modified from Miller's (1956) chunking theory of memory, proposes that expert recognition performance is based upon the presence of many thousands of 'chunks' of information, each representing a domain specific pattern. This internal library of 'chunks' was proposed to develop over many years of experience, further stressing the acquired aspect of expert performance. This extensive knowledge base enabled expert performers to encode presented stimuli as a sequence of 'chunks' by grouping numerous individual features into meaningful 'wholes' and hence circumventing the innate processing limitations of short term memory (7 +/- 2 items). In contrast, the less-skilled or novice performer is not afforded such a luxury and as a result must rely on encoding only a number of solitary pieces. This 'chunking' theory was also able to account for the observed removal of a skill advantage under 'unstructured' conditions as neither expert or novice performers have any stored 'chunks' of random scenes, therefore, regardless of skill, the display is reduced to a series of discrete features.

An alternative theory of expert performance grounded on similar foundations is the 'template matching' theory (Gobet & Simon, 1996). Consistent with 'chunking' theory, in their 'template matching' theory Gobet and Simon (1996) propose that expert performance is governed by an extensive library of situations stored in memory. Rather than representing separate 'chunks' of information, these cognitive stores were proposed to be templates corresponding to whole patterns or scenes. According to the theory, once stimuli are presented the appropriate template(s) is activated and brought under short term memory control. A simple matching process is then undertaken between the current stimulus/situation and the stored template. If a match is made between the present and stored information, the stored template will have an associated response that is appropriate for the situation. Once the template has been activated the performer makes the appropriate response automatically without evaluation or consideration of alternatives. An added feature of the 'template matching' theory is the notion of certain 'core features' which are critical to describing a particular template. However, around these features are 'empty slots' where features can be introduced or removed. Such a flexible approach highlights the ability of expert performers to adapt to new environments that maintain similar structural foundations.

The reliance of 'chunking' theory on the short term memory system proved to be a significant limiting factor in its durability. For example, there was evidence that engagement in a concurrent secondary task that was supposed to disrupt encoding of information in short term memory had no effect on expert performance (e.g., Charness, 1976). Although 'template matching' theory extended upon 'chunking' theory and attempted to account for the ability of skilled players to adapt and respond appropriately in novel environments, it too was flawed by its reliance on short term memory to encode information. To overcome such a limitation, Ericsson and Kintsch (1995) developed long term working memory theory, which emphasises the role of long term memory to encode, store, index and interpret information. Features, or relationships between features within the stimulus/situation, act as retrieval cues to complex structures stored in long term memory. Thus, expert performers enhance the amount of information they hold in working memory by using relatively small retrieval cues to activate rich, complex retrieval structures in long term memory. According to long term working memory theory the retrieval structures that underpin expert behaviour are developed through practice within the domain. Therefore, a novice performer will not have access to the same quality of information as an expert performer from a given retrieval cue.

In long term working memory theory the performer is a cognitively active part of the performance process. Long term working memory is seen to serve two important functions in this respect (Ericsson & Kintsch, 1995). First it enables performers to evaluate an observed context against the retrieval structure, and make evaluation decisions regarding both the current situation and planned future actions thereby providing memory support for performance. Performers can also dynamically construct new retrieval structures through relation to those already stored and predict potential future events, thereby anticipating and preparing for future retrieval demands. This function allows highly skilled performers to prepare and consider future response options before such perceptual information emerges (Harris, Tashman, Ward, Ericsson, Eccles, Williams, Ramrattan, & Lang, 2006). Critically, long term working memory theory holds that the performer is actively engaged in continuous thought during the performance process as they anticipate future events, evaluate potential options, and develop alternative strategies depending on future courses of action. This framework is in contrast to simple recognition type accounts ('chunking', template matching') of expertise where the performer is seen as an almost passive bystander to the matching process (Harris et al., 2006). Such recognition accounts also restrict the performer to respond only on the basis of information available at the present time with no consideration and evaluation of competing or potential future events. The fundamental basis of such recognition accounts is that only information that is currently available can be matched to stored 'templates' or 'chunks' therefore prohibiting consideration of future events. Further still the stored information has a prescribed response associated with it that will be triggered with little or no conscious consideration by the performer once the stored template is activated meaning the performer is unable to consider alternative actions too (Ericsson & Delaney, 1999; Harris et al., 2006). In most sporting competition such processes are likely to be critical to effective performance (Harris et al., 2006). For example, expert snooker players have been shown to engage in deeper planning when evaluating a configuration of snooker balls by considering potential shots several steps in advance (Abernethy et al., 1994).

Identifying the features underpinning expert performance

It is broadly accepted that expert performance is underpinned by the elite performer's ability to identify the most informative display features at the appropriate time, whilst simultaneously disregarding non-relevant and distracting information sources. Important differences have been highlighted in the visual search strategy of skilled and less-skilled performers'. Skilled players' visual search tends to be highlighted by fewer fixations of shorter duration as they fixate and extract information only from the most critical display features in scenarios comprising a restricted number of players (e.g., Helsen & Pauwels, 1993). However the characteristics of skilled visual search also alter depending upon situational constraints as skilled soccer players' demonstrated more fixations of shorter duration when viewing 11-a-side displays (Williams et al., 1994). Clearly the search strategy is governed by task constraints. For scenes containing less information, skilled performers are able to locate their point of gaze at a central feature and utilise peripheral vision to extract information surrounding this point, such that the location for information extraction can be shifted without the corresponding change in fixation location. Thus in displays containing fewer information sources, a skilled performers visual search strategy tends to be characterised by fewer fixations of longer duration. Alternatively, where displays contain numerous diverse features, each potentially rich in information, skilled performers tend to frequently shift fixation location in order to foveate on the appropriate locations, extracting the appropriate information from each source. Therefore in displays containing an array of discrete display features, a skilled performers visual search strategy is characterised by more fixations of shorter duration. Consequently, the greater the complexity of the display the higher the correspondence between point of fixation and information extraction. It is suggested that the experts' extensive task specific knowledge base directs this search strategy (Williams & Davids, 1998). The similar acceptance that these defining perceptual-cognitive features are fashioned as a result of experience as opposed to any innate genetic bias led researchers to question whether such skills could be improved through appropriate training and instruction, and in effect 'shortcut' the years of practice engaged in by experts to initially attain these skills (Abernethy, 1993; Williams & Grant, 1999).

Whilst the theories reviewed previously provide important information and help develop our theoretical understanding of expertise, its nature and development, they were developed as broad all encompassing theories intended to account for expertise in general, irrespective of the domain. These theoretical accounts were unable to inform the sports practitioner or sports scientist as to the specific display features that expert sport performers were utilising to facilitate their expert behaviours. Similarly, until recently a critique levelled at much research into expert anticipation was that it was overly concerned, with focusing primarily on outcome based measures of performance, such as recognition, recall, and anticipation without seriously addressing the processes that accounted for such outcomes.

In the last 10 to 20 years, there has been a notable shift in research attempting to fill this void. Significant strides have been made in addressing the cues assisting expert performance in relatively closed skills and small-sided scenarios. The early work in this area was conducted by Jones and Miles (1978) who employed the temporal occlusion technique by selectively editing test footage at different points in time and asked participants to anticipate shot direction using differing amounts of advance information. Their results indicated that the skilled tennis players made use of advance information cues to make anticipation decisions. Abernethy and colleagues (see Abernethy & Russell, 1984; Abernethy & Russell, 1987) coined the term 'advance cue utilisation' to describe experts' ability to identify critical features early in the evolution of an event or action. An alternative occlusion technique, spatial occlusion, involves editing test footage so that certain display features are occluded throughout and measuring anticipation to examine the effect of removing particular cues on performance. Using such a technique Williams and Davids (1998) reported that skilled players extracted information from the positions and movements of players not in possession for anticipation of 3 vs. 3 sequences. By combining temporal and spatial occlusion techniques, Abernethy and Russell (1987) provided evidence that expert badminton players' superior anticipation of shuttlecock landing position was due to their ability to extract meaningful information from the opponent's racket and racket arm at earlier points in the action sequence. Such investigations acted to stimulate the community of sports scientists and soon research was being conducted to determine the critical cues underpinning expert anticipation across numerous sports. The temporal occlusion paradigm has been used to highlight experts' use of advance information in hockey goalkeeping (Salmela & Fiorito, 1979); cricket (Abernethy & Russell, 1984) and tennis (Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor, 1996).

Eye movement registration systems have also been employed to identify where experts fixate when making their anticipation judgments. In soccer penalty kicks, Savelsbergh, Van der Kamp, Williams, and Ward (2002) report that expert goalkeepers make use of information from both the kicking and non-kicking legs to enable successful saves. Similarly, in the same task, Tyldesley, Bootsma, and Bomhoff (1982) found that expert goalkeepers appeared to gather a lot of information from the penalty taker's hip region. The technique of recording eye movements has also been used in a variety of sports such as tennis (Goulet, Bard, & Fleury, 1989; Williams, Singer, & Weigelt, 1998) and karate (Williams & Elliott, 1999). In extremely fast paced sports (e.g., cricket, volleyball, tennis) skilled performers' are able to quickly locate the object to be acted upon (Allard & Starkes, 1980) and anticipate its likely destination (Ripoll, 1991). Where task constraints dictate the performer must perceive body motion to be successful, skilled performers' adopt a strategy whereby vision is fixated around a central 'anchor' point with peripheral vision employed to extract motion information (e.g., Williams & Elliott, 1999). Although the results of these studies have been pretty consistent in identifying the expert's superiority, in team sports researchers have typically focused on relatively closed skills (e.g., penalty kicks, see Savelsbergh, Williams, Van der Kamp, & Ward, 2002; Williams & Burwitz, 1993) or simple one-on-one, or other small-sided (e.g., 3 vs. 3) situations (e.g., see

Helsen & Pauwels, 1993; Williams & Davids, 1998). Meanwhile, there has been no real progression in understanding the perceptual cues or processing mechanisms controlling expert performance in whole sided open-play environments, and how experts recognise patterns of play.

Aims of the Thesis

General aims and objectives

The overriding aim of the present thesis was to identify the critical information underpinning skilled recognition, and potentially anticipation performance in full-sided open play soccer environments. A series of experiments, each addressing specific issues, were employed in an attempt to satisfy this goal. The broad processing mechanisms by which participants' process displays was investigated to understand the extent to which skilled performance is based upon the identification of higher-order relational information, or alternatively low-level discrete surface features present within the display. Continuing on from this an aim was to identify if certain display features (i.e., players) were more important than others in allowing performers' to make appropriate responses and interpret the display in a meaningful manner. The thesis also aimed to determine whether the signature characteristics of a soccer environment influenced when structure emerged in developing attacking sequences. A final aim sought to identify whether skilled players' perceptual judgments were dependent upon identifying the relationships between players' positions at a given time, or alternatively relied upon the relationships between players' movements over time. Each of these aims is now discussed in turn in greater detail.

Is the display perceived as a function of relationships between features?

The main aim in this thesis is to identify how skilled soccer players process dynamic 11 vs. 11 soccer scenarios when making recognition judgments. The ability to interpret relative motion has been proposed to be fundamental to perception of motion (Dittrich, 1999). Johansson (1973, 1976) first demonstrated that people were still able to perceive and recognise simple human movement patterns when represented as a series of points of light placed at key anatomical locations and termed point light displays. Dittrich and Lea (1994) also demonstrated the importance of relative motion to basic perception of abstract scenes. Considerable evidence has now been presented showing humans' ability to perceive movement patterns via relative motion using point light display presentations (see Bertenthal, Proffitt, Spetner, & Thomas, 1985; Runeson & Frykholm, 1983). Evidence has been presented which would suggest that anticipation skill in racquet sports is also dependent on the ability to pick up information from joint mechanics (see Abernethy & Parker, 1989; Shim & Carlton, 1999; Ward, Williams, & Bennett, 2002) as expert tennis players point-of-gaze alternates between predictive anatomical locations. By comparing anticipation of tennis shots in film and point-light display conditions, Ward et al. (2002) commented that relative kinematic motion might provide the minimal essential information necessary for skilled performance. Specifically it was early relative motions from central body regions (e.g., trunk and hips) that were proposed to allow the experts' advantage. Meanwhile the less-skilled players' focused primarily on isolated distal cues e.g., the racket. It appears that expert performers pick up on intra individual relative motion to inform their anticipation decisions. However, the possibility that elite players in team sports are able to extract inter-individual relative motion to assist their recognition of patterns of play has received little attention. Although an extensive body of literature exists reporting skilled soccer players' superior recognition of soccer scenarios, few researchers have examined whether recognition is a result of perceiving relationships between players or based upon the identification of individual isolated features.

Williams et al. (2006) made an initial attempt to address this issue. Using a counterbalanced design, in one experiment participants viewed a series of sequences in film format, and later made recognition decisions to previously seen or novel sequences presented in film format also. In a second experiment, participants viewed a series of sequences presented in point-light display format, and later made recognition decisions to novel or previously seen point-light display sequences. Although a small decrement in recognition performance was observed when viewing patterns of play presented in point-light rather than film format, skilled performers demonstrated superior recognition performance compared with their less-skilled counterparts. However, by using only one mode of presentation across viewing and recognition it meant that it was possible that even under point-light display conditions participants may still have been recognising isolated features as opposed to relationships. In Chapter 2, using a stricter methodological design by first presenting sequences in film format only and then testing recognition on both film and point-light display sequences, the issue of whether participants process scenes as a function of relationships between features or identify isolated features is examined. It is proposed that for skilled soccer players the linkages between features (players) and their relations in space and time would characterise the display and thus recognition would be a function of relationships between display features.

Are certain features more important than others when recognising playing sequences?

Just as certain features have been shown to be critical to anticipation of filmed displays, and the relationships between key anatomical sites may portray the essential kinematic information, it is possible that the relationships between specific features (players) within a dynamic soccer display are more important than others when recognising patterns of play. The issue of whether certain features are critical in the recognition of dynamic, interactive soccer displays is investigated in Chapters 2 and 3. Using an eye movement registration system, participants' eye movement behaviours were recorded when anticipating and recognising dynamic soccer displays to identify the specific display features that are attended to when making these judgements. However, there are potential limitations in collecting eye movement data in isolation. Fixation location is not directly linked to information extraction (Abernethy, 1988). Secondly, it is possible to shift focus of attention without altering fixation location by using peripheral vision (Williams & Davids, 1997). Given these potential limitations it was necessary to supplement the eye movement data with detailed retrospective verbal reports. These were collected from participants after anticipation and recognition for the purpose of identifying the specific cognitions and thought processes participants engaged in during the processes of anticipation and recognition. It is proposed that the relationships between the central attacking players would be particularly important to skilled decision-making and perception.

Does 'structure' develop incrementally over time, or emerge as discrete, isolated incidents?

The aim in Chapter 4 was to identify the critical time period for information extraction when attempting to recognise sequences of play in dynamic team sports such as soccer. When analysing recognition in team sports researchers have typically used presentation times ranging from 5 to 15 seconds (see, Pimlott, 2001; Smeeton, Ward, & Williams, 2004; Williams & Davids, 1995), yet it is unclear if there is any rationale for these presentation times. An attempt was made to identify the temporal period at which structure emerges in dynamic, interactive sports such as soccer and to provide a clear rationale for a particular stimulus exposure time for forthcoming research. In domains that are less rapidly paced (e.g., baseball, chess, American football), and contain more explicit rules of 'structure' it is probable that the longer duration of stimulus exposure allows the performer to encode and perceive more structure. For example, Paull and Glencross (1997) found that in baseball the more contextual information participants' were provided with, the more accurate their anticipation decisions became. However, soccer does not conform to such rigid rules and is characterised by being highly complex, continually changing, and of varying temporal speed, as well as the interaction of numerous features (Bloomfield, Jonsson, Polman, Houghlan, & O'Donoghue, 2005). It was predicted that given its specific characteristics, structure in soccer would likely emerge in short discrete moments preceding an important attacking event.

Are relationships determined by perception of motions or positions?

In Chapter 5 an attempt was made to determine if relational information within displays emerges as a function of motion relationships between features, or through relationships between features at a given point in time. If, as predicted, skilled performers perceive and process displays as relational information between features, it remains debateable whether the relationships are due to the movements of features or simple positional relationships. To examine this issue skilled and less-skilled players' recognition of attacking sequences presented as dynamic and static sequences was tested. It was predicted based on Dittrich's (1999) interactive encoding model that skilled players' perception of relational information would be based specifically on the perception of relative motion information between features.

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Chapter 2

Perceiving Patterns in Dynamic Action Sequences: Investigating the Processes Underpinning Stimulus Recognition and Anticipation Skill

Abstract

We examined skill-based differences in information processing as participants attempted to anticipate and recognize dynamic displays. Skilled and less-skilled players viewed soccer film sequences and anticipated final pass destination. New and previously viewed action sequences were then presented in film or point-light display format. Players attempted to recognize previously viewed sequences. Skilled players demonstrated superior anticipation skill and were more sensitive in discriminating between previously viewed and novel clips than less-skilled counterparts, regardless of presentation format. Skilled performers fixated more locations than less-skilled players, quickly locating the ball and other critical features. There were no significant correlations between performance on the anticipation and recognition tests, and visual behaviors differed markedly between the two tasks. Skilled players process scenarios as a series of relationships between display features which in turn convey higher-order strategic information. The need to maintain specificity between encoding and retrieval contexts in task instruction and mode of presentation is highlighted for optimal task performance.

Key Words: encoding, retrieval, memory, perception, point-light displays, visual search

The ability to perceive critical information in complex, frequently changing environments is essential for successful performance in many fields of human activity (Williams, Ward, & Smeeton, 2004). This ability is highlighted when performers are required to operate under strict temporal constraints, and is routinely observed in everyday tasks such as driving a car or riding a bike, as well as in elite-level sport. In such situations, performers have to selectively attend only to the most relevant sources of information while ignoring irrelevant or non-regulatory cues. A potentially crucial skill is the ability to identify structure, or meaningful patterns across display features. This skill has been illustrated when attempting to recognize the familiar facial features or gait pattern of a friend from normal or impaired displays (e.g., see Barclay, Cutting, & Kozlowski, 1998; Peterson & Rhodes, 2003), and when attempting to detect threatening pieces in board games such as chess (e.g. Charness, Reingold, Pomplun, & Strampe, 2001) or meaningful patterns of play in a dynamic sport task such as soccer (e.g., Williams, North, Hodges, & Barton, 2006).

In this paper we use a stimulus-recognition paradigm to examine the processing mechanisms used when anticipating outcomes in dynamic scenarios, as well as their subsequent recognition. Also, we examine encoding specificity issues related to task instruction and mode of presentation. The sport of soccer provides an appropriate vehicle to investigate these issues given its dynamic nature and the complex interaction between the ball and offensive/defensive players. When making recognition-based judgments, a number of alternative strategies exist; performers could either recognize stimuli based on isolated features that appear familiar or distinctive, or recognition may be based on the relational information between various features. In order to determine the relative importance of these mechanisms, we manipulate the display to influence the perceptual information available to performers. An eye movement registration technique is employed to identify the specific visual features that individuals focus their gaze upon when attempting to anticipate and make recognition-based judgments.

In cognitive psychology, Goldin (1978, 1979) introduced the use of recognition to study memory differences in novice and expert chess players. Allard, Graham, and Paarsalu (1980) were the first to address this issue in the domain of sport. Skilled and less-skilled basketball players were presented with slides containing both structured (i.e., sequences taken directly from match play) and unstructured (e.g., teams warming up before a match) situations. Half of the slides had been presented during an earlier viewing phase, whereas the remaining half had not. The accuracy with which participants recognized information that had been presented previously was taken as a measure of performance. Skilled basketball players were more accurate than their less-skilled counterparts in recognizing structured slides only. It was argued that skilled players' decisions were based upon recognizing patterns, rather than isolated features, in view of their advantage for structured displays only. The ability to recognize these patterns was seen as an important component of skilled performance. Subsequently, researchers have attempted to better simulate the demands of competition by using dynamic film sequences rather than static slides and measuring both speed and accuracy of response (e.g., see Williams & Davids, 1995). Moreover, a skill advantage for expert memory has also been reported on unstructured stimuli, suggesting that even for stimuli judged to lack structure, experts can identify information that they can use to facilitate encoding and retrieval (Garland & Barry, 1991; Gobet & Simon, 1996; Vicente & Wang, 1998).

The assumption is that skilled performers develop elaborate task-specific retrieval structures that provide them with a significant advantage over less-skilled players when attempting to represent the current situation and identify the likely future outcomes (see Ericsson & Kintsch, 1995; Ericsson, Patel, & Kintsch, 2000). This advantage enables experts to anticipate the consequences of future actions as a result of superior indexing and organization of information at encoding. Skilled performers have been proposed to use their memory skills to construct accurate likelihood ratios as to whether the observed pattern corresponds to one previously viewed (Chappell & Humphreys, 1994). However, the specific information that participants' extract from the display when formulating such likelihood ratios and making recognition-based judgments has not been identified.

Williams et al. (2006) examined the extent to which these judgments are based upon the identification of superficial, low-level surface features (e.g., shirt color, body cues, or environmental or pitch conditions,) or the relational similarity between these features (e.g., the positions or relative orientation of players). Players were required to make recognition-based judgments when sequences of play were presented either under film or point-light display conditions respectively. In the latter condition, the location and movements of players were presented as points of light against a black background, along with the position of the ball within an outline of the field. Although a small decrement in recognition performance was observed when viewing patterns of play presented in point-light rather than film format, particularly on the unstructured sequences, skilled performers demonstrated superior recognition performance compared with their less-skilled counterparts. Skilled performers detect similarity based upon structural relations (e.g., positions of players or their relative orientations) and the higher-order predicates they convey (e.g., the tactical significance of these relations between players; see also Gentner & Markman, 1998).

In a second experiment, Williams et al. (2006) used a spatial occlusion technique to determine whether the relational information between particular players is more important than between others when making recognition-based judgments. The removal of the two central attacking players from the offensive team and their accompanying defensive markers had a detrimental effect on performance, particularly in the skilled group. The positions and movements of these central attacking players and the associated relational and higher-order strategic information conveyed between these players and others within their team provide participants with important information needed to make accurate judgments.

In his interactive encoding model, Dittrich (1999) proposed that skilled performers employ a top-down matching process using stored semantic representations when making recognition-based decisions. Dittrich and Lea (1994) showed that when making perceptual judgements using stimuli involving interactions between several elements, relational information is central to perceiving meaning within the display. Observers were required to detect meaningful motion within a series of dynamic letters. Participants' recognition performance was significantly impaired when the 'goal letter' toward which the 'target letter' was moving was occluded, implying the use of relational information in perceiving and interpreting dynamic scenes. A two-stage process was proposed to be involved combining low- and high-level cognitive processes. First, participants extract motion information, and temporal relationships between features, before matching this stimulus representation with an internal semantic concept or template (cf. Diderjean & Marméche, 2005; Gobet & Simon, 1996).

Regardless of the mechanisms underpinning recognition-based judgments, several researchers have argued that the ability to recognize patterns is essential for appropriate decision making (Abernethy, Neal, & Koning, 1994; Garland & Barry, 1991; Imwold & Hoffman, 1983; Williams & Davids, 1995; Williams et al., 2006). The assumption is that skilled players are able to recognize an evolving pattern of play early in its evolution, allowing them to successfully anticipate the end result of that sequence. An alternative hypothesis is that recognition skill is merely a by-product of exposure to the specific task 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. During performance, individuals are required to anticipate future action requirements rather than to identify a particular pattern of play and consequently, the recognition paradigm may only capture a related function or skill (Ericsson & Lehmann, 1996).

Although recognition performance has been shown to be predictive of anticipation skill in soccer, the overall proportion of the variance across skill groups accounted for by this variable was relatively small (Williams & Davids, 1995). Similar observations about the differences in memory for representative performance have been noted within many other domains of expertise, such as chess and medicine (see Ericsson et al., 2000). Individuals seem to change their cognitive processes to adapt to the demands of the memory task and thus alter the normal processes mediating performance in a representative task that requires action. Some caution should therefore be exercised when studying a task that does not directly involve the execution of superior performance, such as the explicit task of recalling or recognizing presented stimuli instead of the generation of superior actions, such as chess moves or anticipating the actions of soccer players.

According to the encoding specificity principle (Tulving & Thompson, 1973), a change in the nature of the task, or context, between encoding and retrieval impairs memory performance. If different processes are engaged during anticipation compared to those in recognition, performance will be detrimentally affected compared to a situation where the task remains the same across viewing and recognition phases. The demands of the task have been shown to influence how participants direct their attention towards certain stimulus features (West & Craik, 2001). Consequently, different processing strategies may underpin anticipation and recognition. However, if anticipation and recognition involve the same component processes and participants attend to, and extract information from, similar target cues across both encoding and retrieval contexts, no differences will be apparent and retrieval of past experiences may occur automatically (Goldin, 1978; Guynn, McDaniel, & Einstein, 2001; Nowinski & Dismukes, 2005).

In the current paper, the main aim was to examine the type of information used when making recognition-based judgments. We predicted based on the interactive encoding model that skilled players when engaged in a representative task would demonstrate superior recognition performance regardless of whether displays are presented in film or point-light display format during the recognition phase. As part of their encoding of situations in the anticipation task, skilled players will perceive important relational information between players and then match the stimuli presented with the appropriate semantic concept(s) stored in long-term memory. Although less-skilled performers may encode some relational information from the display, when compared to the skilled players they have fewer and/or less elaborate representations in long-term memory to help them interpret stimuli in a meaningful manner. As a consequence, the less-skilled viewers are likely to perceive and encode less relevant information, demonstrating inferior recognition performance for both types of stimuli. We provided a stringent test of this hypothesis by initially presenting participants with action sequences in film format during the anticipation phase and then test their incidental memory by presenting half of these clips in film format and half as point-light displays during the recognition phase. In a previous experiment clips had been presented in a passive manner either as in film or point-light format only during the presentation and recognition phases respectively (see Williams et al., 2006).

An eye movement registration system is employed to examine participants' point-of-gaze when attempting to anticipate and make recognition-based judgments. There is already an extensive literature base to suggest that skilled participants employ more effective and efficient search behaviors compared with less-skilled individuals on other perceptual-cognitive tasks (see Williams, Janelle, & Davids, 2004). For example, when presented with dynamic, film sequences similar to those presented in this experiment, skilled soccer players have been reported to employ more fixations of shorter duration and to be less guilty of 'ball watching', preferring instead to focus on the positions and movements of players (see Helsen & Starkes, 1999; Williams, Davids, Williams, & Burwitz, 1994; Williams & Davids, 1998). However, no researchers have recorded point-of-gaze during performance on a recognition task. This procedure will help highlight the processes that underpin anticipation and recognition, as well as the effects of encoding specificity on perceptual processes. We predicted that, when compared to less-skilled players, the skilled performers would fixate more disparate areas of the display employing more fixations of shorter duration (see Williams et al., 1994). The proposal is the skilled players' more extensive experience with related scenarios and their refined retrieval structures would allow them to interpret the information presented in a meaningful manner. In light of the apparent advantage gained by extracting information from players' positions and movements, as opposed to watching the ball, skilled performers were expected to fixate a wide range of features in order to extract relevant relational information. In contrast, because of their relative lack of ability to attribute meaning to relational information it is unlikely that less-skilled players will search the display in an equally exhaustive manner. Less-skilled participants are predicted to revert to a less sophisticated strategy, preferring to focus on more discrete or superficial elements. The less-skilled players' recognition judgments are likely to be based upon a simple matching template of isolated features, and not the perception and recognition of relational information as predicted by Dittrich (1999).

We also predicted, based on previous research (i.e., Williams et al., 2006), that skilled performers would focus more often than less-skilled players on central attacking players when attempting to make recognition-based decisions. We aimed to examine the relationship between accuracy of anticipation in a representative task and subsequent incidental memory for the same stimuli (film) or degraded stimuli (PLD's). We predict that skilled players will be more accurate at anticipating future events than less-skilled players. Furthermore, we hypothesized that skilled players achieve their superior anticipation through more distinctive encoding in memory and consequently, they are expected to demonstrate superior recognition for stimuli that maintain the structure of the presented action sequences compared to less-skilled participants. We also predict that presenting the stimuli in point-light format would impair recognition performance due to the lack of stimulus similarity across encoding and retrieval, although this degradation was not expected to eliminate the skilled advantage in recognition performance since the relational information is preserved in both contexts. We predict that this effect would be most pronounced for low-structure clips given the relative reduction in relational information.

The current experiment also allowed us to assess if participants engage in similar processing activities when anticipating future actions and making a recognition-based decision. The underlying processing strategies (as reflected by point-of-gaze) will not differ between a task involving the original anticipation of the end result of a pattern of play and that involving observation of the same sequence for subsequent recognition, if similar processing mechanisms are employed for each task. Moreover, we predict a strong correlation between anticipation accuracy and recognition performance. We tested this hypothesis by comparing point-of-gaze during the anticipation phase and when viewing the same sequence for the purpose of recognition. If there are no differences in visual behavior we can assume that the mode of encoding during anticipation and subsequent recognition do not differ, satisfying the encoding-specificity assumption. We predict that encoded features and structural patterns during anticipation would be activated during the subsequent retrieval during the recognition test.

In the present experiment participants were not cued to the location of the ball before the onset of each clip. Since there is evidence that skilled performers are better able to locate the presence of target features, such as the ball, within a display (see Williams, et al., 2004), we predicted that skilled participants would employ fewer fixations than less-skilled players prior to their initial fixation on the ball, whereas more fixations would be used after initial ball detection to allow the important relational information to be encoded.

Method

Participants

A total of 11 skilled and 15 less-skilled male soccer players participated in this experiment. Skilled players (*M* age = 20.6 years, *SD* = 3.1) were professional players at an English Premier League club or were currently playing at a semi-professional level. They had been playing soccer for an average of 12.0 years (*SD* = 2.9) and trained or played for an average of 11.3 hours (*SD* = 4.8) per week. Less-skilled players (*M* age = 25.8 years, *SD* = 4.7) had not participated in the sport above recreational level. They had played soccer for an average of 10.5 years (*SD* = 5.4), albeit relatively infrequently, and currently played for an average of 1 hour (*SD* = 1.2) per week. Participants provided informed consent and were free to withdraw at any stage. 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 Moores University.

Test Film

The test films included offensive sequences of play taken from a sample of three Premier League Academy matches; no matches involved clubs for whom the participants were registered. Footage was captured behind the goal (approximate distance 15 m) from an elevated position (approximate height 10 m). This camera position allowed the complete playing field to be viewed and ensured potentially important information was not lost from wide areas of the field. The camera remained in a static position throughout, with no panning, tilting, zooming or other such functions. This ensured that sequences were recognised solely on information within the display and not extrinsic information such as that related to camera movement. All clips were 5 seconds in duration. Three expert soccer coaches independently rated clips for the level of structure present in each sequence using a Likert-type scale from 0 to 10 (0 being not at all structured, 10 being highly structured). Highly structured clips were sequences of play that were very representative of tactics, maneuvers, and plans typically executed at an elite level, whereas clips lower in structure reflected situations were possession of the ball was in transition and play was relatively less organized. Clips with a mean rating above 7 were classified as high in structure, and clips with a mean rating less than 3 deemed low in structure. All other clips were discarded. The inter-observer agreement was 84.2%. A frame from a typical high structure image is shown in Figure 2.1a. None of the clips would be considered "unstructured" (i.e., random configurations such as when the ball was out of play) as has been the case in previous research.

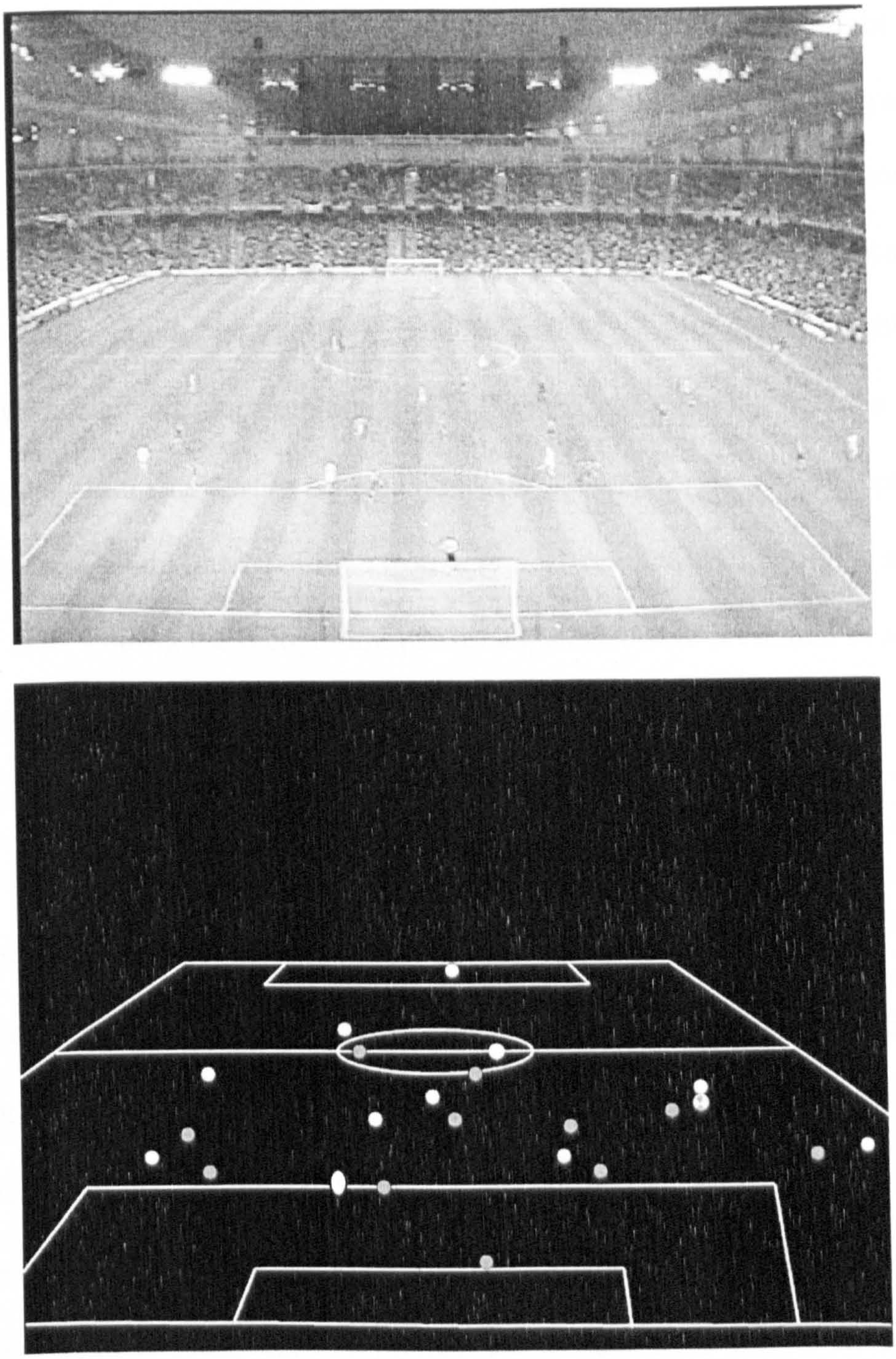


Figure 2.1 A frame from a typical structured trial presented in a) video and b) point-light display format.

The anticipation and recognition phases of the test film each contained 48 action sequences, 24 of which were rated as high in structure and 24 low in structure. In the recognition phase, 24 action sequences had been presented previously during the anticipation phase. The remaining 24 clips in the recognition phase were new. In each set of 24, 12 were rated high and 12 low in structure. Half of each subset of 12 clips was converted into point-light display (PLD) format during the recognition phase only. In the PLD clips, players were represented as points of light against a black background. Players from one team were represented as red points of light, while players on the opposing team were represented as green points of light, and the ball as a white point of light. These colors remained constant from one trial to the next and did not reflect the color of the players' uniforms during the actual matches. Pitch markings were represented by a series of white lines. A frame from a typical structured PLD trial is shown in Figure 2.1b. During the recognition phase, sequences were presented in a random order that was kept constant across participants.

Apparatus

Participants' point-of-gaze was recorded using an Applied Science Laboratories 5000 eye movement registration system (Applied Science Laboratories, Bedford, MA). The system records visual point-of-gaze with respect to a head-mounted scene camera. The system locates two features within the eye, the pupil, and corneal reflection, and by calculating the relative positions of these features to each other, highlights the point-of-gaze by superimposing a crosshair onto a scene camera image. These data were converted into DVD format, and analyzed frame-by-frame using a standard DVD recorder (Panasonic, DMR-E50, Osaka, Japan) sampling at 50 Hz.

Film clips were back projected using a video projection system (Sharp, XG-NV2E, Manchester, UK) onto a 2.1 m x 1.5 m screen (Cinefold, Spiceland, IN). In the recognition phase, a computer-based anticipation timer (VRTAS, Applied Analysis and Integration, Manchester, UK) was used to measure decision time and recognition accuracy. The response interface was comprised of two hand-held push button switches marked either 'yes' or 'no'.

In order to convert clips into PLD format, film sequences were initially saved in ".avi" format using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA). Sampled clips were then exported using IrfanView (www.irfanview.com) to the software package AnalysaSoccer (Liverpool John Moores University, UK). The players were then digitized and reconstructed so that their positions and movements were represented as points of light against a black background using real-time video playback.

Procedure

Participants sat at a desk positioned 3 m away from the centre of the screen. The screen subtended a viewing angle of approximately eight degrees. During the initial anticipation phase, participants were instructed that they would be presented with a series of clips showing attacking patterns of play from various soccer matches, each five seconds in length. Participants were instructed that each clip would be occluded at the moment when the player in possession of the ball was about to make an attacking pass, or take a shot at goal. Participants were required to anticipate the expected pass or shot destination by placing a mark on a schematic representation of the pitch. An inter-trial interval of five seconds was employed. A total of three practice trials were presented.

On completion of the anticipation phase, there was a 10-minute break during which participants completed a practice history questionnaire and responded verbally to a series of questions about their involvement in soccer. Participants were then informed that they would be asked to view a second series of clips and respond by pressing either the 'yes' or 'no' key as to whether the images had been previously viewed in the anticipation phase or were novel. It was also pointed out that some of the clips in the recognition phase would be shown in point-light format as opposed to the original film medium. The concept of point-light displays was fully explained to participants. It was explained that some of the PLD clips represented sequences of play that were shown in the anticipation phase, whereas others were novel. Participants were instructed to respond quickly and accurately. The image was occluded immediately after pressing one of the two response keys to prevent feedback regarding performance on the task.

During the entire test procedure, participants wore the head-mounted corneal-reflection system so as to provide a measure of point-of-gaze as they viewed each clip. The head-mounted optics were fitted to each participant and checked for comfort. The system was calibrated using a 9-point reference grid so the recorded fixation point corresponded to each participant's actual point-of-gaze. Calibration was checked before each of the two test phases and minor adjustments made as necessary.

Dependent Measures and Analysis

Outcome measures.

Anticipation accuracy 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 or correctly anticipated a shot on goal. These data were analyzed 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 structure (high vs. low).

The dependent measures used to evaluate recognition performance were a parametric measure of sensitivity (*d'*), and the criterion (c), a measure of response bias (Green & Swets, 1966). Additionally, decision time was calculated as the time from the start of the clip to the participant's recognition response (in ms). The data for *d'* and c, and decision time were analyzed separately using three, mixed design, 3-way ANOVAs in which the between-participants factor was skill (skilled vs. less skilled) and the within-participants factors were structure (high vs. low) and display (film vs. PLD). Recognition sensitivity (*d'*) and decision time were then correlated separately with performance on the anticipation test using Pearson product moment correlations. Only clips presented in both anticipation and recognition phases were included in the latter analyses. Separate correlations were run for each skill group. We also ran a final correlation between *d'* and anticipation accuracy where the skill groups were collapsed.

Point-of-gaze.

For eye movement data analysis inter- and intra- observer measures of reliability were recorded as 90% and 94.2% respectively.

The data from 8 skilled and 10 less-skilled participants were analyzed. The data from several participants were lost due to technical difficulties where calibration was not achieved successfully or lost during the procedure (e.g., some participants 'disturbed' the position of the head-mounted optics).

Number of fixations. A fixation was defined as a period in which the cursor indicating visual fixation remained on the same location/feature for a period of at least 3 frames (120 ms). The mean number of fixations per second was calculated for each participant.

Number of locations fixated. This measure was the mean number of different features within the display that were fixated in each trial. This value was computed before first fixation on the ball, or player in possession of the ball and after the first fixation on the ball, or player in possession of the ball. We also compared these values for fixations made toward central attacking players on the offensive team, both when they were in possession of the ball and when they were not in possession of the ball.

Fixation duration. This was the average duration of all fixations that occurred when viewing the clips (in ms).

The data were normalized by dividing the number of fixations by the length of time the clip was viewed, producing a per-second value for the number of fixations, number of fixation locations, and number of fixations after locating the ball. The other measures were not affected by response time, and these were analyzed using absolute values. Two types of statistical analyses were performed on the point-of-gaze data. In the first instance, to determine whether different point-of-gaze behaviors were employed during the anticipation and recognition phases, performance was analyzed only on those clips shown in film format during the anticipation phase that were maintained in film format during the recognition phase. Separate mixed-design 2-way ANOVAs were performed on each dependent measure. The between-participants factor was skill (skilled vs. less skilled) and the within-participants factor was phase (anticipation vs. recognition). Second, in order to examine whether point of gaze differed when sequences were viewed in PLD and film format, only point-of-gaze behaviors on clips shown in the recognition phase were assessed. Separate mixed design 2-way ANOVAs were run on each measure with the between-participants factor being skill (skilled vs. less-skilled) and the within-participants factor being display (film vs. PLD). The point-of-gaze data were collapsed across the level of structure due to the lack of any significant main effects for this factor in the outcome data and the fact that all images were considered 'structured' to some degree.

Percentage viewing time as a function of fixation location. Fixations were classified into one of five categories, namely: goalkeepers, defending team, attacking team, ball, and unclassified. Unclassified locations included fixations on features outside the field of play. For each trial, the percentage time spent viewing each of these locations was calculated. A mixed design 3-way ANOVA was used to analyze performance only on clips shown in film format in both anticipation and recognition phases. The between-participants factor was skill (skilled vs. less-skilled) and the within-participants factors were phase (anticipation vs. recognition) and location (goalkeepers vs. defending team vs. attacking team vs. ball vs. unclassified). Another mixed design 3-way ANOVA was performed on recognition phase clips only, where the between-participants factor was skill (skilled vs. less-skilled) and the within-participants factors were display (film vs. PLD) and location (goalkeepers vs. defending team vs. attacking team vs. ball vs. unclassified).

Partial eta squared (η_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. Posthoc Bonferroni corrected comparisons were employed as follow-ups where appropriate. 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).

Results

Outcome Measures

Anticipation

ANOVA revealed a significant difference in performance between skilled and less-skilled players, F (1, 24) = 19.31, p <.001, η_p^2 = .46. Skilled players (M = 64.3%, SD = 6.29) were more accurate than less-skilled (M = 55.7%, SD = 3.85) players, d = 1.64. There was no main effect of structure, F (1, 24) = 1.25, p >.05, η_p^2 = .05, and no Skill x Structure interaction, F (1, 24) = 1.37, p >.05, η_p^2 = .06.

Recognition

The analysis of d' revealed a significant main effect for skill, F (1, 24) = 4.84, p <.05, η_p^2 = .17. Skilled soccer players (M = .41, SD = .66) were more sensitive in distinguishing previously seen from novel stimuli than less-skilled (M = .09, SD = .88) players, d = .41. There was also a significant main effect for display, F (1, 24) = 4.50, p <.005, η_p^2 = .35. Participants were more sensitive in distinguishing previously seen from novel stimuli when presented in film (M = .46, SD = .84) rather than PLD format (M = .04, SD = .71). There was no main effect for structure, F (1, 24) = 2.91, p >.05, η_p^2 = .11. However, there was a significant Structure x Display interaction, F (1, 24) = 3.77, p <.05, η_p^2 = .14. On the high structured clips participants were equally sensitive when distinguishing previously seen from novel stimuli presented in both film (M = .17, SD = .80) and PLD format (M = .12, SD = .52), d = .07, whereas for low structured clips sensitivity was greater for stimuli presented in film (*M* = .76, *SD* = .77) rather than PLD format (*M* = -.04, *SD* = .87), *d* = 1.01. The Skill x Structure, Skill x Display, and Skill x Structure x Display interactions were not significant, *F*'s = .63, .42, and .61, and η_p^2 = .11, .03, and .01 respectively.

The analysis of c revealed a significant main effect for display, *F* (1, 24) = 5.98, $p < .05$, η_p^2 = .20, *d* = .31. Participants showed a lower criterion threshold and consequently, a greater response bias toward responding 'yes' for stimuli presented in film (*M* = -1.9, *SD* = .47) compared with PLD format (*M* = -.02, *SD* = .49). There was also a significant main effect for structure, *F* (1, 24) = 32.05, $p < .001$, η_p^2 = .57, *d* = .88. Participants showed a lower criterion threshold, meaning a greater response bias toward responding 'yes' for high (*M* = -.30, *SD* = .45) compared with low structure (*M* = .10, *SD* = .44) clips. There was no main effect for skill, *F* (1, 24) = .17, $p > .05$, η_p^2 = .01. The Skill x Structure, Skill x Display, Structure x Display, and Skill x Structure x Display interactions were not significant, *F*'s = .87, 3.34, .07, and .31, and η_p^2 = .04, .12, .00, and .01 respectively, all *p*'s >.05.

Analysis of decision time data revealed no significant main effects for skill, structure, or display, *F* (1, 24) = 1.14, 1.52, and .30, and η_p^2 = .05, .06, and .01 respectively, all *p's* > .05. The Structure x Skill, Display x Skill, Structure x Display, and Skill x Structure x Display were not significant, *F* (1, 24) = .81, .17, 2.16, and .99, and η_p^2 = .03, .01, .08, and .04 respectively, all *p*'s > .05. Mean decision time was 4.21 seconds (SD = 0.82).

There was no significant correlation between anticipation accuracy and decision time for the skilled players, *r* (9) = -.186, or between anticipation accuracy and either decision time or *d'* for the less-skilled players, *r* (13) = .131, and .075, respectively, all p's > .1. However, there was a moderate, yet non-significant correlation between anticipation and d' for skilled players, r (9) = .436, p = .18. When participants were collapsed across skill, there was again a moderate yet non-significant correlation between anticipation and d', r (24) = .386, p = .06.

Point-of-Gaze

Analysis of action sequences presented in film format in both anticipation and recognition phases.

ANOVAs were used to analyze point-of-gaze data on clips shown in film format during the anticipation and recognition phases. The main effects and interactions between skill level and viewing phase were of particular interest. Since there were no significant main effects for structure on decision time and recognition accuracy, the clips were collapsed across structure.

Number of fixations. ANOVA revealed a significant main effect for viewing phase, F (1, 16) = 9.097, p <.01, η_p^2 = .362. Participants had more fixations during the anticipation phase (M = 1.27, SD = 0.32) compared with the recognition phase (M = 1.12, SD = 0.19), d = 0.57. However, there was no significant main effect for skill, F (1, 16) = 2.36, η_p^2 = .13, and no Phase x Skill interaction, F (1, 16) = 0.25, η_p^2 = .02, p > .05.

Total number of fixation locations. A significant main effect for skill was observed, F (1, 16) = 5.98, p <.05, η_p^2 = .27. Skilled participants fixated more locations per second (M = 1.03, SD = 0.19) than less-skilled players (M = 0.89, SD

Table 2.2: Point of gaze behaviour for skilled and less-skilled participants (GK = goalkeeper, Def = defending team, Att = attacking team, Ball = ball, U/C = unclassified)

Skilled										
						% Viewing Time				
Task	Fixations (per second)	Locations (per second)	Mean Duration (ms)	Fix Pre-ball	Fix Post-Ball (per second)	GK	Def	Att	Ball	U/C
Anticipation	1.40 (.56)	1.01 (.37)	610.7 (491.1)	1.24 (1.32)	.84 (.59)	.58 (.6)	8.85 (4.6)	25.54 (8.3)	59.15 (12.3)	5.14 (6.9)
Film Recognition	1.14 (.52)	.98 (.39)	1001.1 (658.2)	1.05 (1.07)	.56 (.53)	2.16 (4.1)	4.78 (3.1)	13.35 (4.5)	78.15 (3.7)	1.55 (1.1)
PLD Recognition	.88 (.43)	.81 (.31)	1170.6 (826.8)	1.02 (.8)	.32 (.41)	.37 (.8)	3.65 (2)	12.21 (7.9)	82.49 (10.1)	1.42 (1.4)

Less skilled										
						% Viewing Time				
Task	Fixations (per second)	Locations (per second)	Mean Duration (ms)	Fix Pre-ball	Fix Post-Ball (per second)	GK	Def	Att	Ball	U/C
Anticipation	1.21 (.52)	.89 (.36)	755.3 (702.5)	1.71 (1.46)	.54 (.5)	1.34 (1.9)	4.92 (3.8)	22.86 (12)	66.94 (12.1)	4.25 (3.5)
Film Recognition	1.03 (.48)	.88 (.36)	954.9 (778.1)	1.56 (1.45)	.36 (.37)	2.97 (3.3)	7.93 (7.1)	12.99 (5.1)	72.65 (9.2)	3.26 (2.4)
PLD Recognition	.80 (.41)	.68 (.28)	1222.8 (784.4)	.91 (1.15)	.30 (.35)	.37 (.8)	3.28 (4.3)	8.75 (7.7)	85.25 (11.2)	2.02 (2.4)

= 0.14), d = 0.84. There was no significant main effect of phase and no Skill x Phase interaction, F (1, 16) = 1.30, and 0.81, and η_p^2 = .08, and .05 respectively, both p's > .05.

Mean number of fixations before locating the ball. There was a significant main effect for skill, F (1, 16) = 11.70, p <.01, η_p^2 = .42. Skilled players (M = 1.14, SD = 0.37) employed fewer fixations before locating the ball than less-skilled players (M = 1.63, SD = 0.47), d = 1.16. There was no main effect for phase, and no Skill x Phase interaction, F (1, 16) = 1.38, and 0.02, η_p^2 = .08, and .001 respectively, both p's > .05.

Mean number of fixations after locating the ball. ANOVA revealed a significant main effect for phase, F (1, 16) = 11.51, p<.005, η_p^2 = .418. Participants made more fixations per second after locating the ball for clips in the anticipation phase (M = 0.69, SD = 0.33) compared with the recognition phase (M = 0.46, SD = 0.20), d = 0.84. There was also a significant main effect for skill, F (1, 16) = 6.65, p <.05, η_p^2 = .294. Skilled players (M = 0.70, SD = 0.30) made more fixations per second after locating the ball than less-skilled players (M= 0.45, SD = 0.25), d = 0.91. There was no Phase x Skill interaction, F (1, 16) = .62, η_p^2 = .04, p > .05.

Fixations on central attacking players. There was no main effect for skill when the central attacking players were in possession of the ball, F (1, 16) = 3.56, p > .05, d = 0.91. However, there was a significant effect when not in possession of the ball, F (1, 16) = 5.77, p < .05, d = 1.18. Skilled participants (M = .62, SD = .12) made more fixations to central attacking players off the ball than less-skilled players (M = .46, SD = .15). When combining fixations on central attacking players that were both in, and not in, possession of the ball there was a main effect for skill, F (1, 16) = 6.96, p< .05, d = 1.29. Skilled participants (M = 1.02, SD = .21) made more fixations on central attacking players than less-skilled participants (M= .75, SD = .21).

Fixation duration. There was a main effect for phase, F (1, 16) = 27.35, p <.001, η_p^2 = .63. Participants employed shorter fixations to clips in the anticipation (M = 683.0 ms, SD = 296.6) compared with recognition phase (M = 978.0 ms, SD = 284.2), d = 1.02. There was no main effect for skill, F (1, 16) = .15, η_p^2 = .01, p >.05, and no Skill x Phase interaction, F (1, 16) = 2.86, η_p^2 = .15, p >.05.

Percentage viewing time. The data for this analysis are illustrated in Figure 2.3. ANOVA revealed a significant main effect for location, F (1.85, 29.59) = 453.73, p <.001, η_p^2 = .97, but no main effect for skill or phase, F = 0.21, and 0.01, and η_p^2 = .01, and .00 respectively, both p's > .05. Bonferroni corrected pairwise comparisons showed that more time was spent fixating the defending team, the attacking team, and the ball compared to the goalkeeper. In addition, more time was spent fixating the attacking than the defending team, and also the ball in comparison to both the attacking and defending team. Lastly, participants spent more time viewing the attacking team and the ball than unclassified locations, all p's < .005. A significant Phase x Location interaction was observed, F (1.73, 27.75) = 13.87, p <.001, η_p^2 = .46. Participants spent more time viewing the ball and less time viewing the attacking team during the recognition phase (Ball: M = 75.4 %,. SD = 7.67 vs. Attack: M = 13.2%, SD = 4.72), d = 9.77, in comparison to the anticipation phase (Ball: M = 63%, SD =

12.49 vs. Attack: $M = 24.2\%$, $SD = 10.32$), $d = 3.39$. The Skill x Phase x Location interaction was not significant, F (1.73, 27.75) = 2.93, $p = .077$, $\eta_p^2 = .16$.

Analysis of point light and film sequences in recognition phase only.

ANOVAs were used to analyze point-of-gaze data from the recognition phase clips only. The main effects and interactions between skill and display (film and PLD) were of particular interest.

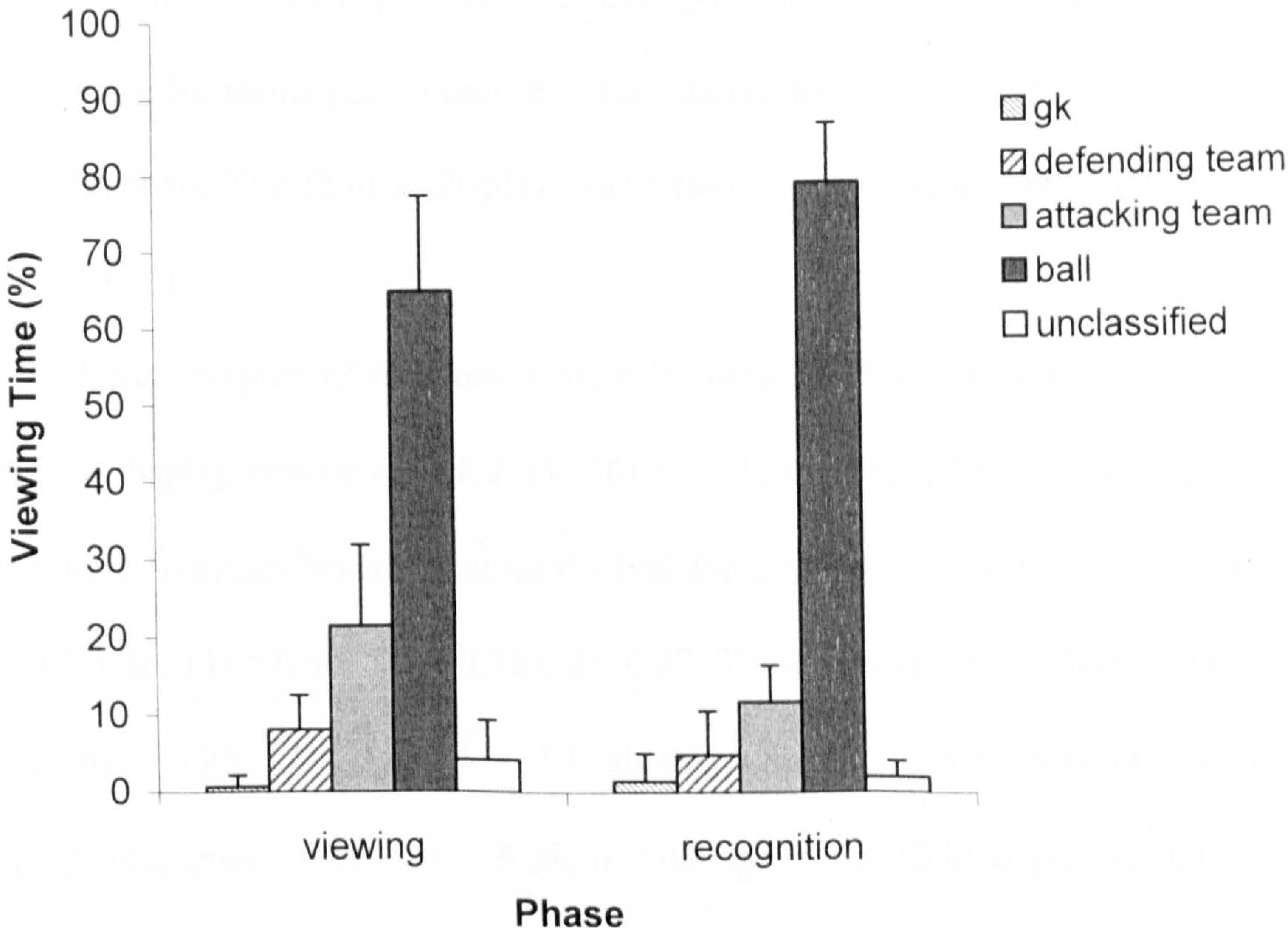


Figure 2.3. Location x Phase interaction for % viewing time, for clips shown in film format during both anticipation and recognition phases only. (gk = goalkeeper).

Number of fixations. ANOVA revealed a significant main effect for display, F (1, 16) = 20.05, $p < .001$, $\eta_p^2 = .57$. Participants employed more fixations per second when viewing film ($M = 1.08$, $SD = 0.19$) compared with PLD clips ($M = 0.84$, $SD = 0.22$), $d = 1.17$. The effect of skill, and the Skill x

Display interaction were not significant, F = 1.41, and 0.09, and η_p^2 = .08, and .01 respectively, both p's > .05.

Total number of fixation locations. There was a significant main effect for display, F (1, 16) = 31.28, p<.001, η_p^2 = .66. Participants fixated more locations per second for clips in film (M = 1.04, SD = 0.24) compared with PLD format (M = 0.74, SD = 0.15), d = 1.50. There was also a significant main effect of skill, F (1, 16) = 11.05, p<.005, η_p^2 = .409. Skilled participants (M = 0.99, SD = 0.26) fixated more locations per second than less-skilled participants (M = 0.79, SD = 0.20), d = 0.86. The Skill x Display interaction was not significant F (1, 16) = 1.84, η_p^2 = .11.

Mean number of fixations before locating the ball. A significant main effect for display was observed, F (1, 16) = 7.51, p <.05, η_p^2 = .32. Participants made more fixations before locating the ball for film (M = 1.30, SD = 0.40) than for PLD clips (M = 0.96, SD = 0.38), d = 0.87. There was no main effect for skill, F (1, 16) = 3.25, p > .05, η_p^2 = .17, although there was a significant Skill x Display interaction, F (1, 16) = 6.18, p <.05, η_p^2 = .28. Skilled players did not differ in the number of fixations employed before locating the ball in the film and PLD clips (M = 1.05, SD = 0.25 vs. M = 1.02, SD = 0.30, d = 0.11), whereas less skilled players made more fixations before locating the ball for film than PLD clips (M = 1.56, SD = 0.35 vs. M = 0.91, SD = 0.45, d = 1.61).

Mean number of fixations after locating the ball. ANOVA revealed a significant main effect for display, F (1, 16) = 15.10, p <.005, η_p^2 = .49. Participants showed more fixations per second after locating the ball for film (M = 0.46, SD = 0.20) compared with PLD clips (M = 0.31, SD = 0.17), d = 0.81. There was a significant Display x Skill interaction, F (1, 16) = 4.41, p <.05, η_p^2 =

.22. The number of fixations used by less-skilled players after locating the ball did not differ between film and PLD (M = 0.36, SD = 0.18 vs. M = 0.30, SD= 0.11, d = 0.40), whereas skilled players employed more fixations after locating the ball for film than PLD clips (M = 0.56, SD = 0.16 vs. M = 0.32, SD = 0.24, d = 1.18). There was no main effect for skill, F (1, 16) = 2.18, p > .05, η_p^2 = .12.

Fixation duration. There were no significant effects for skill or display, and no significant Skill x Display interaction, F (1, 16) = .00, 3.48, and .18, and η_p^2 = .00, .18, and .01 respectively, all p's > .05.

Percentage viewing time. There were no significant effects for skill, F (1, 16) = 1.72, η_p^2 = .10. A significant main effect for location was observed, F (1.42, 22.64) = 915.09, p <.001, η_p^2 = .98. Bonferroni corrected pairwise comparisons showed a number of significant differences. Less time was spent fixating the goalkeepers than the defending team, attacking team, and ball. Less time was spent viewing the defending team than either the attacking team, or ball. Less time was spent viewing unclassified locations than either the defending or attacking teams. Lastly, more time was spent viewing the ball than the attacking team or unclassified locations, all p's < .05.

There was a significant Display x Location interaction, F (1.73, 27.60) = 5.55, p <.05, η_p^2 = .258, as illustrated in Figure 2.4. Participants spent less time viewing the ball when clips were viewed in film (M = 75.4%, SD = 7.67) compared with PLD (M = 83.9%, SD = 10.6) format, d = 0.92. However, the reverse was found for percentage time spent viewing attacking and defending teams, with more time being spent viewing these areas in film compared to PLD format. The Skill x Display, Skill x Location, and Skill x Display x Location interactions were not significant, F's = .84, .45, and 1.38, and η_p^2 = .00, .03, and

.08 respectively, all p's > .05. There was no main effect for skill and no main effect of display, $F = 1.72$, and 0.00, and $\eta_p^2 = 1.0$, and .00 respectively, both p's > .05.

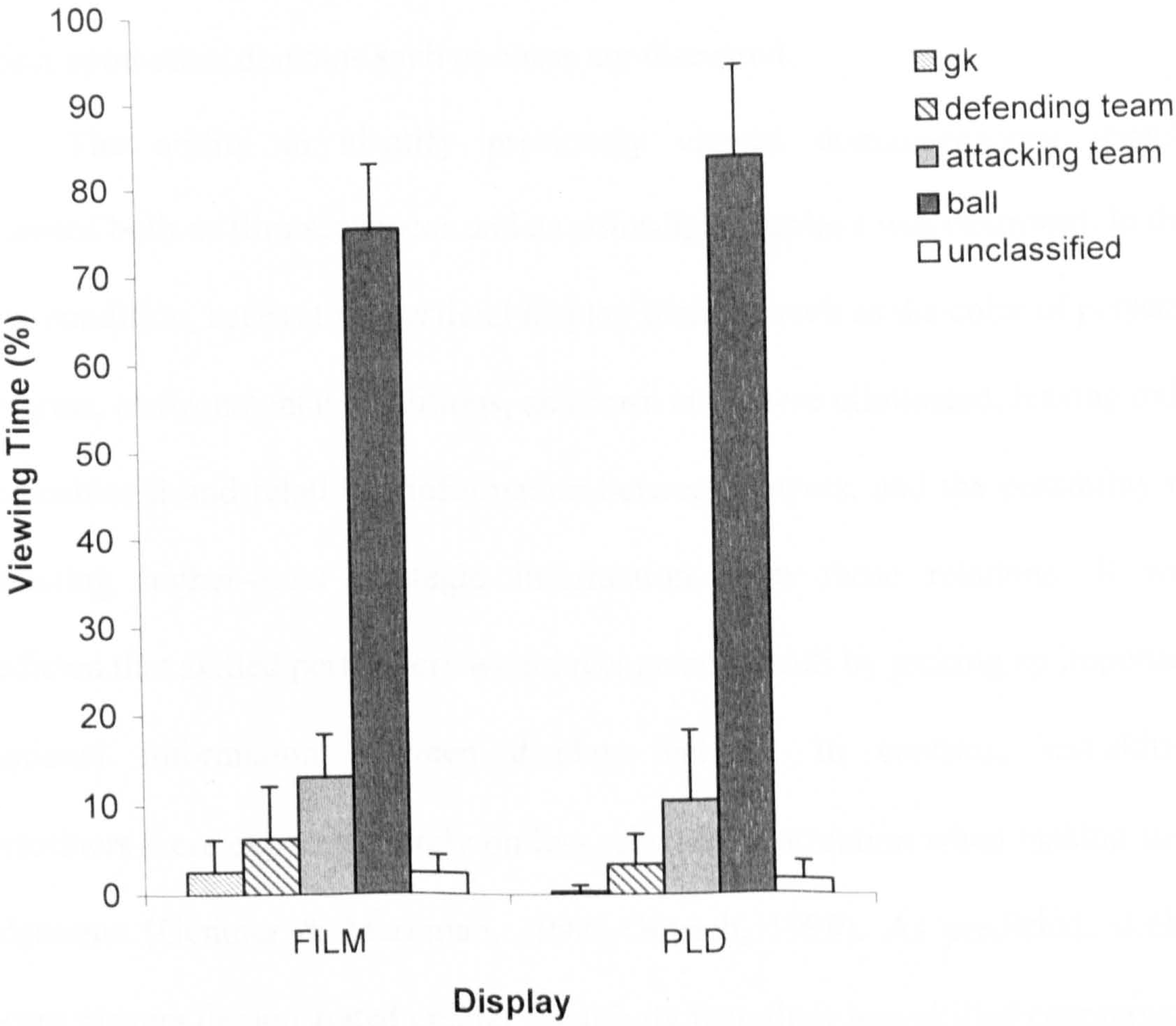


Figure 2.4. Location x Display interaction for % viewing time, on recognition phase clips in both film and PLD format. (gk = goalkeeper, PLD = point light display).

Discussion

In this paper our main aim was to identify the processes underpinning anticipation and recognition-based judgments. Moreover, we attempted to identify the extent to which pattern recognition underpins anticipation skill using a stimulus-recognition paradigm and by manipulating the display such that varying levels of information were provided to participants while simultaneously recording point-of-gaze to assess the focus of attention. We begin by discussing differences in performance and process as a function of skill, before addressing the impact of altering task instruction and presentation format. Finally, the broader issues which are raised by this research and how these could potentially impact upon other domains such as chess are discussed.

The ability to identify previously viewed domain-relevant stimuli presented both as film sequences and as point-light displays was examined. In the latter condition, access to superficial display features such as the color of players' uniforms, environmental conditions, and form cues were eliminated, leaving only the positional and relational information between players, and the possibility of extracting higher-order strategic information from these relations. It was predicted that skilled performers would recognize stimuli by picking up important relational information between display features. In contrast, less-skilled performers were expected to rely on less relevant information when making such judgments (Gentner & Markman, 1998; Dittrich, 1999). As predicted, skilled soccer players demonstrated greater sensitivity than their less-skilled counterparts in distinguishing previously seen from novel stimuli for both display conditions. Furthermore, there were no differences between the groups in terms of response bias. Skilled performers maintained their superiority over less-skilled counterparts even when sequences are presented in point-light rather than video format during recognition (see also Williams et al., 2006).

According to the interactive-encoding model proposed by Dittrich (1999), skilled players are able to combine low- and high-level cognitive processes when making recognition-based judgements. Participants are initially thought to extract motion information, and temporal relationships between features, before matching this stimulus representation with an internal semantic concept or template. As a resulted of extended skill acquisition within their domain of expertise, skilled players are thought to acquire more refined encoding methods in long-term memory which enables them to more accurately process and interpret the relational information present within the display (Ericsson & Delaney, 1999; Ericsson & Kintsch, 1995).

Although skilled participants maintained their superiority over less-skilled counterparts when viewing point-light compared with film sequences, some decrement in performance was apparent for both groups of players. Since the point-light manipulation ensured that both formats were structurally similar, the removal of superficial characteristics was likely the primary cause of the observed decrement in performance. Superficial, low-level surface features appear to offer both groups of performers some useful contextual information alongside the available relational information to aid recognition, especially in low-structure stimuli. However, film displays do not only contain low-level surface information. The transition to point-light presentation format also means that behavioural and postural information is removed. Clearly such postural information may be important when viewing sporting sequences (see Williams, Davids, & Williams, 1999 for a review) and potentially it is the removal of this information that impacted upon performance once film displays were converted into the point-light format.

The analysis of point-of-gaze data confirmed that the two skill groups differed in degree rather than in structure as shown by the virtual absence of reliable interactions with skill. Skilled players fixated on more locations than less-skilled players regardless of presentation format during the recognition tests.

Another important difference was that skilled players employed fewer fixations before, and more fixations after, locating the ball than less-skilled players. An important task early in each sequence is to locate the position of the ball since most information is likely to be relative to its position on the field. It appears that skilled players are better than less-skilled performers at locating the presence of target features in the display, requiring fewer fixations before this point. After the location of the ball has been detected, skilled players are less guilty of 'ball watching' preferring to focus their gaze more broadly on the positions and movements of players 'off the ball'. This finding further suggests that the ability to pick up important relational information is critical to scene perception (Dittrich & Lee, 1994).

An important implication of the skilled participants' superior recognition performance is that when these players are asked to perform a representative task the way in which they encode and index information results in superior incidental memory for, and consequently access to, that information. Moreover, the results from the point-light condition suggest that when information is initially processed in a manner that is consistent with performance in their domain of expertise (i.e., anticipation) the encoded information is likely to be largely structural in nature, implying that skilled players engage in pattern recognition to recognize stimuli comprising interaction between several features.

The point-of-gaze data were collected to provide insight into whether the eye movement behaviors during recognition are indicative of processing a particular type of information (i.e., relational versus superficial features), and whether certain features were more important to skilled performance. These behaviors also helped to elucidate on the similarity (or differences) in processes underlying anticipation and recognition. Skill-based differences in visual behaviors were observed. As predicted (see Williams et al., 2006), the skilled performers fixated more frequently on the central attacking players than the less-skilled players in both anticipation and recognition phases. These data suggest that the relational information provided by these players, and potentially their offensive colleagues, is crucial when attempting to recognize sequences of play. The skilled players fixated more frequently on the central offensive players when they were not in possession of the ball, while there was no skill-based difference in the number of fixations to these features when they were in possession. The skilled players fixated more disparate areas of the display than less-skilled players, providing support for previous research involving the anticipation of offensive sequences of play (see Williams et al., 1994). This finding was observed for action sequences presented in both film and point-light format, demonstrating that skilled performers maintain a similar viewing strategy regardless of the presentation mode. Moreover, this latter finding would provide support for the assumption that skilled players process complex displays based upon relationships between features and their associated higher-order predicates, whereas less-skilled players do so to a lesser degree (see also Gentner & Markman, 1997).

The skilled soccer players demonstrated superior anticipation skill compared to less-skilled players (Ward & Williams, 2003; Williams, et al., 1994). However, we were particularly interested in the correlations between anticipation and recognition performance. While a moderate positive correlation (r = .436) was observed between performances on the anticipation test and recognition sensitivity on the film clips for the skilled players, neither this correlation, nor the aggregate correlation for all players (r = .386) were significant. Although some evidence has been provided to argue that skilled players may engage in some sort of pattern recognition process when making recognition-based judgments (i.e., showing a skill advantage for point-light stimuli and eye movements that indicate a broad, relation-based perceptual strategy), stimulus recognition is likely to involve additional cognitive processes. Moreover, anticipation itself is likely to be even more complex in terms of the processes underlying successful performance. It is therefore difficult to determine whether recognition is a central component of anticipation skill. Although evidence has been provided to suggest that skilled players may recognize patterns when identifying stimuli, the extent to which anticipation skill is dependent on pattern recognition is less clear.

A number of significant differences in visual search behavior were apparent as a function of the mode of presentation and task instructions provided to participants. Participants fixated fewer locations and had fewer fixations both before and after locating the position of the ball in point-light compared with film format. Also, players spent more time fixating the ball and less time on attacking and defensive players when viewing point-light rather than film clips during the recognition phase (see also Ward et al., 2002). The visual search behaviors were more consistent across anticipation and recognition for film clips than those in point-light format. When the presented stimulus features are identical across task contexts, the processes underpinning recognition are maintained to a greater extent than when both task and stimulus features differ. Specificity of display may be equally as important as the task instructions during encoding. Clearly the effect of presenting film displays first followed by point-light displays has a potential impact on performance. It may be interesting to first present sequences in a point-light format, and test later recognition on film sequences. In such an instance, skilled recognition may be enhanced as the relational information that we propose they prioritise is highlighted during encoding. However, the encoding specificity principle is a potential confound that would still need to be taken into consideration.

When participants were instructed to anticipate the likely ending of the film clip, rather than to identify whether or not they had previously viewed the sequence, they fixated on more locations, showed an increased number of fixations after locating the ball, recorded shorter fixation durations, and spent less time fixating the ball and more time viewing the offensive team. It appears that the two tasks require somewhat different processing strategies. According to the encoding-specificity principle, the task context determines how participants' process information and if different processes are engaged during the encoding stage this will not bode well for later recall or recognition. A recent study of text comprehension supports these findings (Allbritton, 2004). When participants were asked to read a paragraph of text for the purposes of determining what happens next, their response time to a word probe was faster when the word could be anticipated from the previously-read text than when they were instructed to recall names of individuals that were central to the story. The implication is that when individuals engage in tasks that encourage elaborative encoding of information in a manner consistent with the demands of the task domain, they are more likely to be able to access this information for the purposes of prediction than when engaging in tasks that discourage such activity. As a result, the underlying processing strategies are likely to differ significantly.

The differences in processing strategies employed in both tasks may provide an explanation for the relatively low perceptual sensitivity scores reported in this paper. This change in task instruction between encoding and retrieval appeared to have a detrimental effect on memory performance. West and Craik (2001) observed that changing the nature of a task can affect how people allocate their attention to the display (see also, Yarbus, 1967). Furthermore, the finding that recognition performance is most impaired for stimuli in point-light rather than film format reinforces the importance of the match between processes engaged during encoding and testing. The decrement in performance when participants are shown point light rather than film displays might be indicative of the different processing operations engaged during viewing of the two different stimuli during the recognition phase. When specificity of task and stimulus display is inconsistent, recognition performance suffers the most and processing strategy differs markedly, implying that in such scenarios the information is encoded to a very shallow level of processing and consequently performance suffers. It is important to note, however, that while performance was poorer than expected during recognition, the skilled players still outperformed less-skilled players. This finding suggests that skilled performers are more able to encode information in a meaningful way such that the future retrieval demands can be anticipated, even when the same information is to be recalled for a different purpose (see Ericsson & Kintsch, 1995).

Regarding interpretation of eye movement data a note of caution should be sounded given some inherent limitations with such data. Individuals may shift their point of attention with shifting their point of visual fixation (Williams & Davids, 1998), and there is the important distinction between 'looking' and 'seeing' (Papin, Metges, & Amelberti, 1984). However, as complexity of display increases so too does the link between point of gaze and information extraction. For example, where the display is relatively simple performers have been reported to utilise peripheral vision (see Williams & Elliott, 1997), implying a low relationship between point of gaze and information extraction. However, for tasks involving complex displays, point of gaze corresponds more directly with information extraction and is evidenced in studies of aircraft pilot (Bellenkes, Wickens, & Kramer, 1997) and driving simulations (Horrey, Wickens, & Consalus, 2006). Thus given the complexity of display in the present study, one can be confident that point of gaze is closely related to information extraction.

The instructions for participants to respond as 'quickly and accurately' as possible may have potentially impacted upon the results via a speed-accuracy trade-off as some participants favoured to satisfy the speed element but sacrificed accuracy, whereas others adopted the opposite strategy. The phenomenon of the speed-accuracy trade off was first analysed by Fitts (1954) in an investigation into the relationship between speed and accuracy as subjects were required to manually 'tap' between two separate targets. However, the present study and its methodological protocol attempted to capture as accurately as possible the real-world performance characteristics of the soccer task. Clearly, in soccer and similar pursuits, the need to anticipate accurately is paramount, however given the externally paced temporal nature of these environments so too is the need to respond quickly. Further still, when recording eye movement data, if performers were not allowed to dictate the response time it would likely result in a collection of 'dead' eye movement data that was in fact irrelevant to the decision making process, thus acting as a confound on the eye movement data. Such a factor is highlighted as a potential limitation in the eye movement data collected by Helsen and Stakes (1999). Therefore whilst it is important to acknowledge the potential impact of a speed-accuracy trade off on the data, it was felt to be an important component of the current design.

In her study of chess, Goldin (1978) demonstrated that selecting the next move or evaluating a presented chess position enhanced subsequent incidental memory by contrasting the effects of different encoding tasks. Completing this representative task of playing chess games led to superior incidental memory than tasks such as counting pieces or copying the positions. These findings were not explicitly tested in this study, but it is important to highlight the varying task demands. In chess the positions of pieces remain fixed throughout, whereas in soccer its dynamic nature means that the positions and relations between features are constantly changing. The current instruction to respond quickly as well as accurately during the recognition phase could also mean that performers responded before the final action, the point at which they were required to make their anticipation decision. In this case, recognition decisions could have been based upon different structural and relational information than the information used to anticipate the outcome. In view of the static nature of pieces in chess, the recognition and anticipation decisions will have been made on identical relational information regardless of when a decision is made.

Additional evidence for the use of relational information in making recognition judgments comes from the reduced ability to recognize low-structured clips in the point-light condition, reflected in the Structure x Display interaction. This finding suggests that this format is only useful for conveying highly structured information, such as that found in the meaningful relations between players during a formulated offensive play. Presumably, access to important relational information is reduced in low-structure sequences compared with high structure clips and consequently, these patterns are constrained to be processed on the basis of superficial display features only. Given that any meaningful surface features have been removed by the point-light manipulation, their interpretation is largely meaningless, compared to low-structure film clips where participants are still able to utilize some contextual information to make sense of the information presented.

The Structure x Display interaction is an interesting finding. The higher recognition accuracy for low-structure clips appears contrary to the literature regarding expertise and expert memory recall. However, this finding is consistent with other observations on recognition memory. While memory recall is superior for high- compared with low-frequency words (Ward, Woodward, Stevens, & Stinson, 2003), when asked to recognize such stimuli the reverse is true (Guttentag & Carroll, 1997). The same findings are also observed for recall and recognition of high and low frequency pictures (Karlsen & Snodgrass, 2004). Karlson and Snodgrass (2004) suggest that "...if the paradox is indeed a general effect of frequency/familiarity, it should be present in other domains" (p.275), and assuming the high- and low-structure displays used in the present paper are analogous to the high- and low-frequency words and pictures of previous research then it appears these findings have been replicated across the recognition of high- and low-structure patterns in dynamic sports. The results are consistent with the Search of Associative Memory (SAM) model (Gillund & Shiffrin, 1984) where accordingly all words/cues have associative links to other words/cues stored in memory. Low-frequency/structure cues have less associated cues in memory, therefore low-frequency/structure stimuli that have been presented previously appear more distinctive than previously presented high frequency/structure stimuli that have many associated and thus interfering cues in memory. In view of the absence of a Skill x Structure interaction, we are careful not to put too much emphasis on any findings involving structure. All the slides were "structured" as determined by expert coaches and as such their ability to discriminate across skill class appears to have been undermined (although this was not our primary objective).

In this paper we showed that skilled performers are able to pick up the relational information between elements, and process stimuli as a series of patterns. We make the inference that this information conveys important, higher-order strategic information that can be meaningfully encoded by skilled participants into appropriate retrieval structures. A number of systematic differences in visual behaviors across skill groups were observed. Most notably, the skilled players appeared particularly reliant on information from the central offensive players and potentially, although not verified here, their relations to other players. We have provided evidence to show that when attempting to recognize familiar and unfamiliar sequences or patterns it is important to maintain similarity with the context in which the information is encoded. This importance of encoding specificity across encoding and retrieval contexts was highlighted both in relation to the task and mode of presentation.

Chapter 3

The Mechanisms Underlying Skilled Anticipation and Recognition in a Dynamic and Temporally Constrained Domain

Abstract

We examined the mechanisms underlying skilled anticipation and recognition in a dynamic, temporally constrained domain. Skilled and less-skilled participants viewed soccer film sequences and anticipated final pass destination. Previously viewed and novel sequences were then presented in film or point light display format. Players made recognition judgments to each sequence and retrospective verbal reports were gathered. Skilled soccer players demonstrated superior anticipation skill and were more sensitive in distinguishing previously seen from novel stimuli than less-skilled participants, across both film and point light display formats, and with no difference in response bias. Skilled performers utilized more complex memory representations, indicated by references to more stimuli, actions, and deeper cognitions. The complexity of representations activated was reduced during recognition compared with anticipation, although skilled participants still demonstrated more complex structures. Both skilled and less-skilled players' representations were enhanced when recognizing in point light display compared to film format. Our results support a LTWM framework to interpret expert performance in dynamic, temporally demanding domains with numerous elements.

Key words: expert performance; anticipation; recognition; point light display; verbal reports

As outlined in Chapter 2 the ability to identify critical information sources, often within complex, rapidly changing displays is an important component of many human behaviours, in particular those that operate under strict temporal constraints. Examples of such tasks include driving a motor vehicle and participating in elite level sport. Regardless of the domain, the task is to selectively attend to the most information rich sources, while disregarding redundant information. This skill has been demonstrated when recognizing the facial features and gait patterns of acquaintances (e.g., Peterson & Rhodes, 2003), assessing threatening playing pieces in chess (e.g., Charness, Reingold, Pomplun, & Strampe, 2001), and recognizing developing patterns of play in invasion sports such as soccer (e.g., Williams, North, Hodges, & Barton, 2006).

In the present study we used a stimulus-recognition paradigm and collected retrospective verbal reports to examine the processing mechanisms and critical features used to make anticipation decisions, and subsequent recognition judgments. In light of its dynamic nature, and the interaction between numerous elements, soccer was chosen as an appropriate medium to investigate these issues. As highlighted in Chapter 2, when recognizing sequences of play, participants may recognize isolated features that appear distinctive, or alternatively, they may recognize familiar relationships between features. Thus far, researchers (e.g., Williams, et al., 2006; North, Williams, Hodges, Ward, & Ericsson, submitted) have shown that skilled individuals perceive scenes using the latter strategy, whereas, in contrast, less-skilled performers are more likely to rely on superficial display features when recognizing sequences of play. We further tested these assumptions by manipulating the display and varying the amount of perceptual information available to performers. Moreover, we examined in greater detail the thought processes employed by collecting retrospective verbal reports in order to enhance our understanding of the processing mechanisms underpinning effective performance. The collection of immediate retrospective verbal reports, and examination of the thought processes engaged in, allowed the specific features that individuals process and attend to when anticipating and recognizing to be identified.

The recognition paradigm has its roots in cognitive psychology and the study of expert memory in chess (Goldin, 1978, 1979). The technique was first applied to the sporting domain by Allard, Graham, and Paarsalu (1980) as reviewed in Chapter 2. The finding that expert basketball players were more accurate in recognition than their novice peers on structured stimuli only was taken as evidence that skilled players' decisions are based upon recognizing the relationships and patterns within the display. As outlined in Chapter 2 this finding has since been replicated by numerous authors across several domains implying that recognition skill is an important component of skilled performance.

It is proposed that elite level performers develop complex task-specific retrieval structures following many hours of engagement in deliberate practice. These retrieval structures allow experts to efficiently and effectively index and store information at encoding, such that single features serve as cues to activate retrieval structures, and permit superior mental representation of current scenarios and anticipation of future events compared to their novice counterparts (Ericsson & Kintsch, 1995; Ericsson, Patel, & Kintsch, 2000). It is also proposed that elite performers utilize these memory processes and retrieval structures to form likelihood ratios when making recognition decisions as to whether sequences have been presented previously or not (Chappell & Humphreys, 1994).

Thus far, few researchers have attempted to identify the specific sources of information that performers use when attempting to make familiarity-based judgments. In a recent exception, reviewed in more detail in Chapter 2, Williams et al. (2006) compared recognition performance on film and point-light sequences to provide evidence that skilled soccer players process scenes as a function of structural and relational information within the display, whilst less-skilled performers rely on identification of isolated superficial features.

In a follow-up study, North, Williams, Hodges, Ward and Ericsson (submitted) analyzed the visual search behaviors employed by participants in order to identify the specific features fixated upon when anticipating and making recognition judgments. The data indicated that the positions and movements of the central attacking players were especially important in relation to the position of the ball. The method of recording point-of-gaze data is frequently employed across domains to examine the processes relating to skilled anticipation. For example, researchers have shown that skilled drivers fixate further ahead in the road than novice drivers, enabling them to anticipate potential road hazards (McKenna & Horswill, 1999). Similarly, experienced pilots make more fixations to appropriate locations within the cockpit and toward the runway when flying and landing than novice pilots (Bellenkes, Wickens & Kramer, 1997). North et al. (submitted) were the first to examine the visual behaviors used during recognition, although this method had previously been used to examine anticipation skill in sport (e.g., Ward, Williams, & Bennett, 2002; Williams & Davids, 1998; Williams, Davids, Burwitz, & Williams 1994).

However, the conclusions drawn from data gathered via eye movement recording techniques are not without limitations. Fixation location does not necessarily imply information extraction (Abernethy, 1988). Participants may fixate in a passive manner and refrain from extracting information from the area fixated. This effect is commonly referred to as the distinction between 'looking' and 'seeing' (e.g., Papin, Metges, & Amelberti, 1984). Also, individuals can relocate their point of attention without alternating their point-of-gaze (Williams & Davids, 1998). Although the fovea may be directed toward a particular location, information may be extracted from elsewhere using the visual periphery. Therefore, while the findings from North, et al. (submitted) are potentially informative in identifying the features processed by skilled performers, they must be interpreted with a note of caution. It is necessary to use complementary methodological techniques to strengthen these claims and overcome the potential limitations (Williams & Ericsson, 2005).

The collection of verbal reports not only serves to compliment the data from eye movement recordings, but also provides valuable insight into the organization of skilled memory and the storage and processing activities within these structures. Over the years several theoretical accounts of expert memory have been articulated and later rejected as researchers have subsequently questioned their validity and applicability. Simon and Chase (1973) proposed that skilled performers were able to circumvent the limitations of storage in short term memory by grouping individual items into meaningful "chunks", allowing them to store more information. This proposal was reinforced when data showed that although skilled players demonstrated an advantage for 'structured' stimuli, no skill advantage was found for 'unstructured' displays where no meaningful information was contained, thus prohibiting the "chunking" of information (Chase & Simon, 1973). An alternative theory also based upon transient storage in short term memory is the recognition/matching approach (Gobet & Simon, 1996), where stimuli in short term memory activate stored memory traces, bringing them into consciousness and allowing a simple matching process to be undertaken, under the control of short term memory. These 'chunking' and 'recognition' theories were shown to be flawed however when it was reported that introducing a secondary task to disrupt the encoding of information in short term memory had no effect on memory performance (Frey & Adesman, 1976).

The model proposed by Ericsson and Kintsch (1995) emphasizes the use of long term memory (LTM) to encode, store, index, and interpret information. Complex retrieval structures in LTM are believed to remain accessible through cues held in short term memory. This representation, combining cues in STM and complex information structures in LTM was termed long term working memory (LTWM). However, the retrieval structures in LTM are developed as a function of deliberate practice accumulated in the domain. Consequently, less-skilled individuals, or performers who have spent less time engaging in deliberate practice, will not be able to activate the level of information that skilled performers can from a given retrieval cue.

LTWM is suggested to serve two important purposes (Ericsson & Kintsch, 1995). First, through interpreting retrieval cues and the present situation in relation to stored retrieval structures it facilitates performers in monitoring a situation, making alternative planning actions, and continually evaluating both the present situation and potential planned actions. Second, due to a skilled performers domain specific knowledge, it enables retrieval structures to be constructed dynamically "on-the-go". Consequently, highly skilled performers can anticipate future occurrences, predict the outcome of these, and develop effective reactive behaviors and calculate the demands that will be placed upon them. Clearly, in many 'real world' tasks, as evident in the sporting domain, where the environment is dynamic and complex, involving numerous potential features, the performer must often respond to partial sources of information and engage in reasoning behaviors in an efficient and meaningful manner (Harris et al., 2006). A recognition account of expert memory is unable to adequately explain skilled performance since this approach suggests that performers must be constrained to act on early perceptual information, or at best information in the present, and would also be unable to consider and evaluate competing potential outcomes (Ericsson & Delaney, 1999). The LTWM account of expert performance overcomes these limitations. For example, research on text comprehension (Kintsch, 1998) and medical diagnosis (Ericsson & Kintsch, 1995) indicate that skilled performers, in the respective fields, have cognitive representations of scenarios that permit the encoding of information in a manner to aid prediction, analysis, and evaluation.

It is important to demonstrate that in rapid, temporally demanding situations, skilled performers process displays in a manner that is consistent with a LTWM account. The domain of soccer represents a situation that is extremely dynamic, performers often have to make decisions under severe temporal constraint, and making the right or wrong decision can be the difference between winning and losing a match. The rapid nature of the skilled performer's decisions under these situational constraints implies that outcomes are chosen automatically upon recognition of a given stimulus. However, we contend that skilled soccer players' store and index information in memory in an efficient and effective manner that constrains the planning and selection of the appropriate action.

In this study we examined the performance of skilled and less-skilled soccer players on film-based tests of anticipation and recognition skill respectively. We collected retrospective verbal reports to help identify the specific features attended to and provide insight into the cognitive representations held by these players. Also, we examined whether a recognition or LTWM account is best to interpret skilled behavior in such domains. Given the task, and the ability of skilled players to operate effectively in this environment, we predicted that for skilled players the retrospective verbal reports would reflect a memory representation that facilitates the use of information to make accurate anticipations, and evaluate alternative outcomes; information that is more in line with the constructs of LTWM than a recognition account. Thus, we predicted that skilled players would demonstrate superior anticipation than less-skilled players. In addition to viewing the display in such a manner, the skilled players extensive, and rich memory representations would allow them to index and store the encoded information in such a manner as to allow rapid retrieval at a later time. Therefore, we also predicted that skilled players would perform better on the recognition test. Given previous findings (North et al, submitted; Williams et al, 2006) and theories of skilled perception (Dittrich, 1999; Dittrich & Lea, 1994) it was predicted that skilled players would maintain this advantage for film and point light display conditions.

When anticipating we predicted that skilled players' complex memory representations would be evidenced by verbalizing more anticipation predictions, more potential option statements, and more task relevant evaluations. In contrast however, less-skilled players' representations would be less complex and so verbal reports would focus more heavily on monitoring statements. If recognition is an important skill underpinning anticipation, then similar observations should be recorded when recognizing film displays. However, the findings from North et al (submitted) using eye movement data suggest that skilled performers would make more monitoring statements relative to anticipation predictions, option statements, and task relevant evaluations. When recognizing in point light format skilled participants were predicted to verbalize more anticipation predictions, option statements and task relevant evaluations than less-skilled players due to their rich memory representations, and the fact that any distracting or non-relevant information was removed from the display. It was predicted that when anticipating skilled participants verbal reports would make particular reference to the movements of central attacking players, whereas less-skilled soccer players' verbal reports would be more dominated by statements toward the ball or player in possession of the ball (cf. North et al., submitted). Furthermore, it was hypothesized that when attempting to recognize sequences, both in film and point light display, skilled soccer players would make less reference to the central attacking players and more toward the ball or player in possession of the ball. Finally, we predicted that skilled soccer players' complex representations and awareness of more alternative courses of action would result in more varied action statements when anticipating than less-skilled players. Given our earlier prediction that skilled players' verbal reports would show more reference to central attacking players we argue that the action statements of skilled players would refer to runs and movements off the ball. Also, as we predict that skilled players would refer less to central attacking players when recognizing, in turn we therefore predict that when recognizing less action statements would be made to runs and movements off the ball, and more action statements would be made to movements of the ball such as simple passes, and passes across the defense.

Method

Participants

A total of 11 skilled and 8 less-skilled male soccer players participated. Skilled players (*M* age = 25.5 years, *SD* = 4) were all currently playing at a semi-professional level, and 9 of these had previously played for professional soccer clubs in England. They had been playing soccer for an average of 15.1 years (*SD* = 3.1) and currently trained or played for an average of 9 hours (*SD* = 2.4) per week. Less-skilled players (*M* age = 24 years, *SD* = 1.6) had not participated in the sport above recreational level. They had played soccer for an average of 11.1 years (*SD* = 3.3), although they currently played for an average of only 0.4 hours (*SD* = 0.7) per week. Participants provided informed consent and were free to withdraw at any stage. All participants reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of the institution.

Test Film

The test films included offensive sequences of play taken from the same battery of clips used in Chapter 2, such that the filming position, clip duration, and rating protocol for each sequence were the same as outlined in the methodology of Chapter 2. As in Chapter 2, clips with a mean rating above 7 were classified as high in structure, and those with a mean rating less than 3 deemed low in structure. All other clips were discarded. The inter-observer agreement was 84.2%. A frame from a typical high structure image is shown in

Figure 3.1a. None of the clips would be considered "unstructured" (i.e., random configurations such as when the ball was out of play) as has been the case in the majority of previous research.

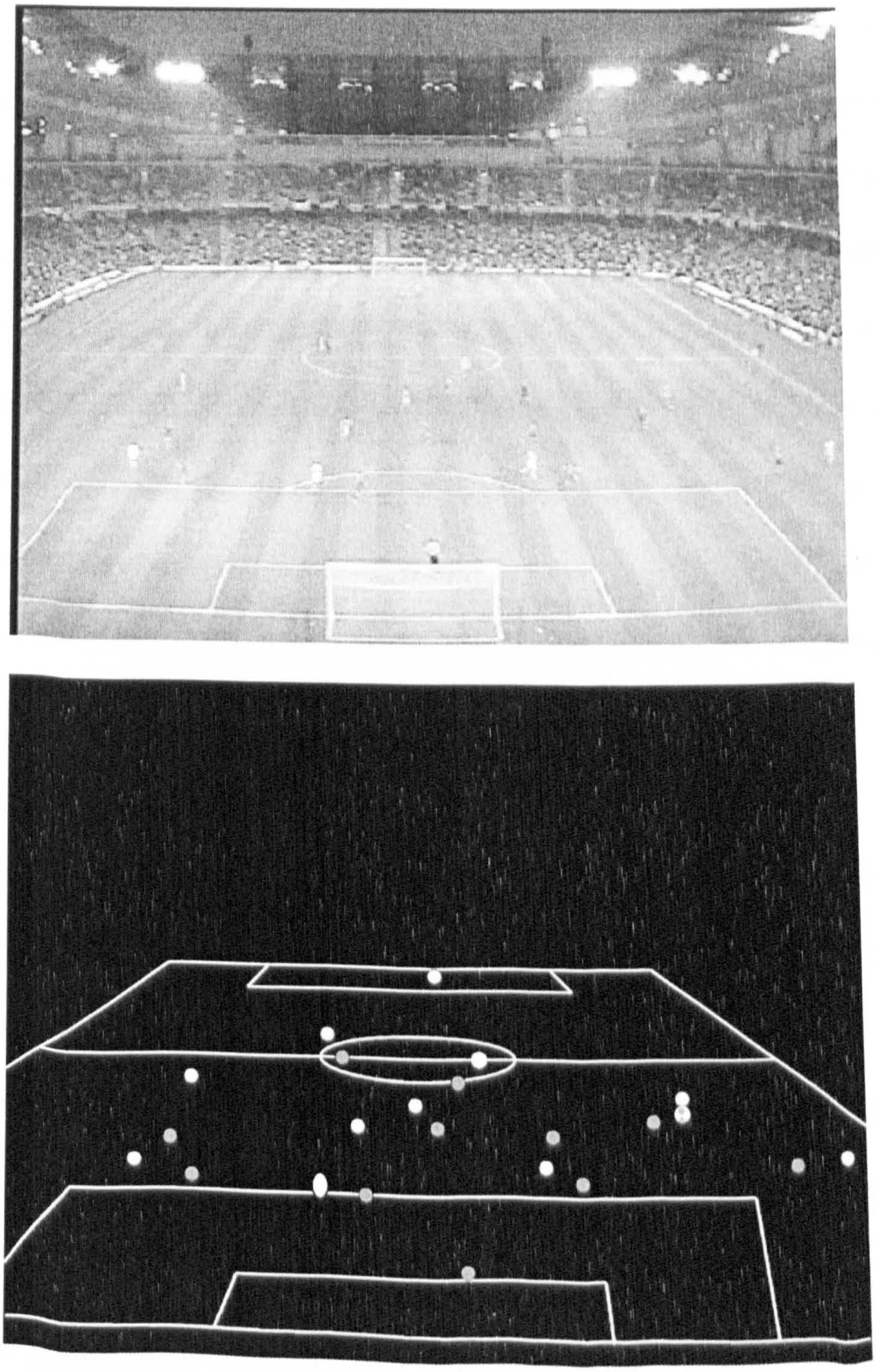


Figure 3.1. A frame from a typical structured trial presented in a) video and b) point-light display format.

The anticipation and recognition phases of the test film each contained 24 action sequences, 12 of which were rated as high in structure and 12 low in structure. In the recognition phase, 12 action sequences had been presented previously during the anticipation phase. The remaining 12 clips in the recognition phase were new. In each set of 12, 6 were rated high and 6 low in structure. Half of each subset of 6 clips was converted into point-light display format during the recognition phase only. In the point-light display clips, players were represented as points of light against a black background. Players from one team were represented as red points of light, while players on the opposing team were represented as green points of light, and the ball as a white point of light. These colors remained constant from one trial to the next and did not reflect the color of the players' uniforms during the actual matches. Pitch markings were represented by a series of white lines. A frame from a typical structured point-light display trial is shown in Figure 3.1b. During the recognition phase, sequences were presented in a random order that was kept constant across participants.

Apparatus

Film clips were back projected using a video projection system (Sharp, XG-NV2E, Manchester, UK) onto a 9' x 12' screen (Cinefold, Spiceland, IN). In the recognition phase, a computer-based anticipation timer (VRTAS, Applied Analysis and Integration, Manchester, UK) was used to measure decision-time and recognition accuracy. The response interface was comprised of two hand-held push button switches marked either 'yes' or 'no'.

In order to convert clips into point-light display format, film sequences were initially saved in ".avi" format using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA). Sampled clips were then exported using IrfanView (www.irfanview.com) to the software package AnalysaSoccer (Liverpool John Moores University, UK). The players' positions and movements on film were then digitized and reconstructed so that they were represented as points of light against a black background using real-time video playback.

Procedure

Prior to completing the experimental tasks participants' were instructed and trained how to think aloud and provide retrospective verbal reports. The instruction and training protocol were the same as those by Ericsson and Kirk (2001), which, in turn, were adapted from Ericsson and Simon's (1993) original instructions. Several domain specific examples were included as part of the training protocol. The training session included instruction and practice at thinking aloud, retrospectively reporting these thoughts using a range of generic problems and task specific video-based scenarios. Training continued until participants were comfortable with the procedure of providing retrospective verbal reports and the criteria for omitting type III verbal reports were satisfied (see Ericsson & Simon, 1993). The verbal report training protocol lasted approximately from 0.75 to 1.25 hours.

Once training had been completed, participants stood at a raised desk positioned 3m away from the center of the screen. The screen subtended a viewing angle of approximately eight degrees. During the initial anticipation phase, participants were instructed that they would be presented with a series of clips showing attacking patterns of play from various soccer matches, each 5 seconds in length. Participants were instructed that each clip would be occluded at the moment when the player in possession of the ball was about to make an attacking pass, or take a shot at goal. Participants were required to anticipate the expected pass or shot destination by placing a mark on a schematic representation of the pitch. An inter-trial interval of 5 seconds was employed. Participants were also instructed that after certain trials once they had made an anticipation decision they would be asked to think aloud and provide detailed retrospective verbal reports of their thoughts while viewing the action stimuli and making their anticipation decision. In addition to the stimuli used as part of the training protocol, a total of three practice trials were presented. Retrospective verbal reports were collected after every practice trial. During the experimental anticipation phase, retrospective verbal reports were collected after the second trial, and every other trial thereafter.

On completion of the anticipation phase, there was a 10-minute break during which participants completed a practice history questionnaire and responded verbally to a series of questions about their involvement in soccer. Participants were informed that they would be asked to view a second series of clips, some that had been presented previously in the anticipation phase, and some that were novel. Participants were instructed their task was to make a familiarity judgment in relation to each clip by pressing one of two switches marked 'yes' or 'no' as to whether it had or had not been shown earlier during the anticipation phase. Participants were also informed that some of the clips in the recognition phase would be shown in point-light display format as opposed to the original film medium. The concept of point-light displays was fully explained to participants and three practice examples shown in their original film format and point light display conversion. It was explained that some of the point-light display clips represented sequences of play that were shown in the anticipation phase, whereas others were novel. Participants were instructed to respond quickly and accurately. The image was occluded immediately after pressing one of the two response keys to prevent feedback regarding performance on the task. Participants were again instructed that for certain trials once they had made a recognition decision they would be asked to provide a retrospective verbal report detailing their thoughts while viewing the sequence and making their recognition judgment. Retrospective verbal reports were collected after the first recognition trial and every other trial thereafter.

Dependent Measures and Analysis

Outcome measures.

Anticipation accuracy 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 or correctly anticipated a shot on goal. These data were analyzed 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 structure (high vs. low).

The dependent measures used to evaluate recognition performance were a parametric measure of sensitivity (*d'*) and the criterion (c), a measure of response bias (Green & Swets, 1966). Additionally, decision time was calculated as the time from the start of the clip to the participant's recognition response (in ms). The data for *d'* and c, and decision time, were analyzed separately using three, mixed design 3-way ANOVAs in which the between-participants factor was skill (skilled vs. less skilled) and the within-participants factors were structure (high vs. low) and display (film vs. point-light display).

Verbal Reports

For analysis of verbal report data both inter- and intra- observer reliability were recorded, and reported as 89% and 95.4% respectively.

Participants' retrospective verbal reports were transcribed verbatim and segmented using natural speech and other syntactical markers. The retrospective verbal reports were then categorically coded on three separate classification schemes, namely types of action, types of stimuli, and types of cognition.

Actions

Actions were typically verbs that described behaviors or specified types of play (e.g. pass, cross, dribble). Retrospective verbal reports were analyzed inductively when coding the types of action. All action statements were listed, producing 109 separate action statements in total. These statements were subsequently grouped into similar action statements, allowing 16 distinct types of action categories to emerge from the data. The final action categories that emerged from the data were: hand gestures; passing across the defense; short passes; directional passes; long aerial passes; passes into space; body shape/posture; turning; attacking runs/movements off the ball; make space; pressuring; movement into central space; movement into wide space; defensive marking; collective movements.

Stimuli

Stimuli were features within the display to which the participants referred. The same procedure was used to inductively analyze the types of stimuli as used to analyze the types of action. In total 46 types of stimuli were mentioned. These stimuli were then grouped into similar references, allowing 15 distinct types of stimuli to emerge from the data. The final types of stimuli that emerged from the data were: superficial features; goalkeepers; ball and player in possession; attacking team central attackers; attacking team defensive unit; attacking team wide defenders; attacking team central defenders; attacking team wide midfield players; attacking team central midfield players; empty areas/space; whole team(s); defending team defense; defending team midfield; defending team attackers; defending team player pressuring the ball.

Cognitions

Statements were coded according to the type of information that was reported. With coding statements as the type of cognition and level of information it conveyed, a semi-inductive method of analysis was used. Initially, statements were coded as monitoring statements, predictions (subdivided into anticipation and option predictions), planning, and evaluations (see Ward, Ericsson, & Williams, in preparation). However, additional categories emerged from the data, and it became necessary to modify these existing categories. Finally, 10 categories for types of cognition were used to code statements:

Monitoring statements on the pitch. Statements recalling current actions involving on-pitch events.

Monitoring statements off the pitch. Statements recalling current actions involving off-pitch events.

Anticipation predictions. Statements predicting/anticipating the future event.

Option predictions. Statements that do not directly predict the future event, but highlighted other potential future events.

Deep planning. Statements referring to predictions of events further into the future beyond the next immediate step.

Inferences. Statements stressing information that is not immediately present or available in the display.

Task-relevant evaluations. A statement making some form of comparison, assessment, or appraisal of events/features that are situation/task/context relevant.

Irrelevant evaluations. A statement making some form of comparison, assessment, or appraisal of events/features that are not relevant to the situation/task/context.

Relevant questions. Questioning statements that refer to potential evaluations and inferences.

Irrelevant questions. Questioning statements that refer to potential irrelevant information.

Two types of statistical analysis were performed on the verbal report data for each classification scheme. First, to determine whether different thought processes were engaged during the anticipation and recognition phases, retrospective verbal reports were analyzed on one clip shown in film format during the anticipation phase that was maintained in film format during the recognition phase. The clip selected for analysis was that which most distinguished skilled participants from less-skilled participants in both anticipation and recognition tasks. The data were analyzed using three separate mixed design 3-way ANOVA's. The between participants factor was skill (skilled vs. less-skilled), and the within participants factors were phase (anticipation vs. recognition) and action (i.e., the 16 categories highlighted above), or stimuli (i.e., the 15 categories listed above), or cognition (i.e., the 10 categories outlined previously) depending on the classification scheme being analyzed.

Second, in order to examine whether thought processes differed across sequences presented in point-light display and film format, retrospective verbal reports were analyzed for a clip shown in film format and a clip presented in point-light display format in the recognition phase. The film format clip was kept consistent as for the anticipation vs. recognition comparison. The point-light display format clip was that which most distinguished skilled from less-skilled participants in recognition performance, and was also structurally similar to the film format clip. Three separate mixed design 3-way ANOVA's were again used to analyze the data. The between participants factor was skill (skilled vs. less skilled), and the within participants factors were display (film vs. point-light display) and action (i.e., the 16 categories highlighted above), or stimuli (i.e., the 15 categories listed above), or cognition (i.e., the 10 categories outlined previously) depending on the classification scheme being analyzed.

Partial eta squared (η_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 where there are comparisons between two means. Post-hoc Bonferroni corrected comparisons were employed as follow-ups where appropriate. 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).

Results

Outcome Measures

Anticipation

ANOVA revealed a significant difference in performance between skilled and less-skilled players, $F(1, 17) = 22.4, p < .001, \eta_p^2 = .57$. Skilled players ($M$ = 65.3%, SD = 8.16) were more accurate than less-skilled (M = 46.8%, SD = 8.7) players, $d = 2.2$. There was no main effect of structure, $F(1, 17) = .42, p > .05, \eta_p^2 = .02$, and no Skill x Structure interaction, $F(1, 17) = .92, p > .05, \eta_p^2 = .05$.

Recognition

The analysis of d' revealed a significant main effect for skill $F(1, 17) = 21.1, p < .01, \eta_p^2 = .55$. Skilled soccer players (M = .80, SD = .60) were more sensitive in distinguishing previously seen from novel stimuli than less-skilled (M = .36, SD = .71) players, $d = .70$. There was no main effect for structure or display, $F(1, 17) = 4.3$, and 3.8, and $\eta_p^2 = .20$, and .18 respectively, both p's >.05. The Structure x Skill, Display x Skill, Structure x Display, and Skill x Structure x Display interactions were not significant F's $(1,17) = .07$, .05, .01, and .31, and $\eta_p^2 = .00$, .00, .00, and .02 respectively, all p's >.05.

The analysis of c revealed a significant main effect for structure, $F(1, 17) = 60.78, p < .001, \eta_p^2 = .78, d = 1.33$. Participants showed a lower criterion threshold and consequently, a greater response bias toward responding 'yes' for high structured stimuli (M = -.29, SD = .42) compared with low structured stimuli (M = .22, SD = .34). There was no main effect for skill or display, $F(1, 17) = 1.0$, and .00, and $\eta_p^2 = .06$, and .00 respectively, both p's >.05. The Skill x Structure, Skill x Display, Structure x Display, and Skill x Structure x Display interactions were not significant, $F(1, 17) = .01$, .36, .01, and 2.0, and $\eta_p^2 = .00$, .02, .00, and .10 respectively, all p's >.05.

Analysis of decision time data revealed no significant main effects for skill, structure, or display, $F(1, 17) = .33$, .05, and 2.55, and $\eta_p^2 = .02$, .00, and .13

respectively, all p's > .05. The Structure x Skill, Display x Skill, Structure x Display, and Skill x Structure x Display were not significant, F (1, 17) = .34, .05, 1.56, and .11, and η_p^2 = .02, .00, .08, and .01 respectively, all p's > .05.

Verbal Reports

Analysis of an action sequence presented in film format in both anticipation and recognition phases.

Actions

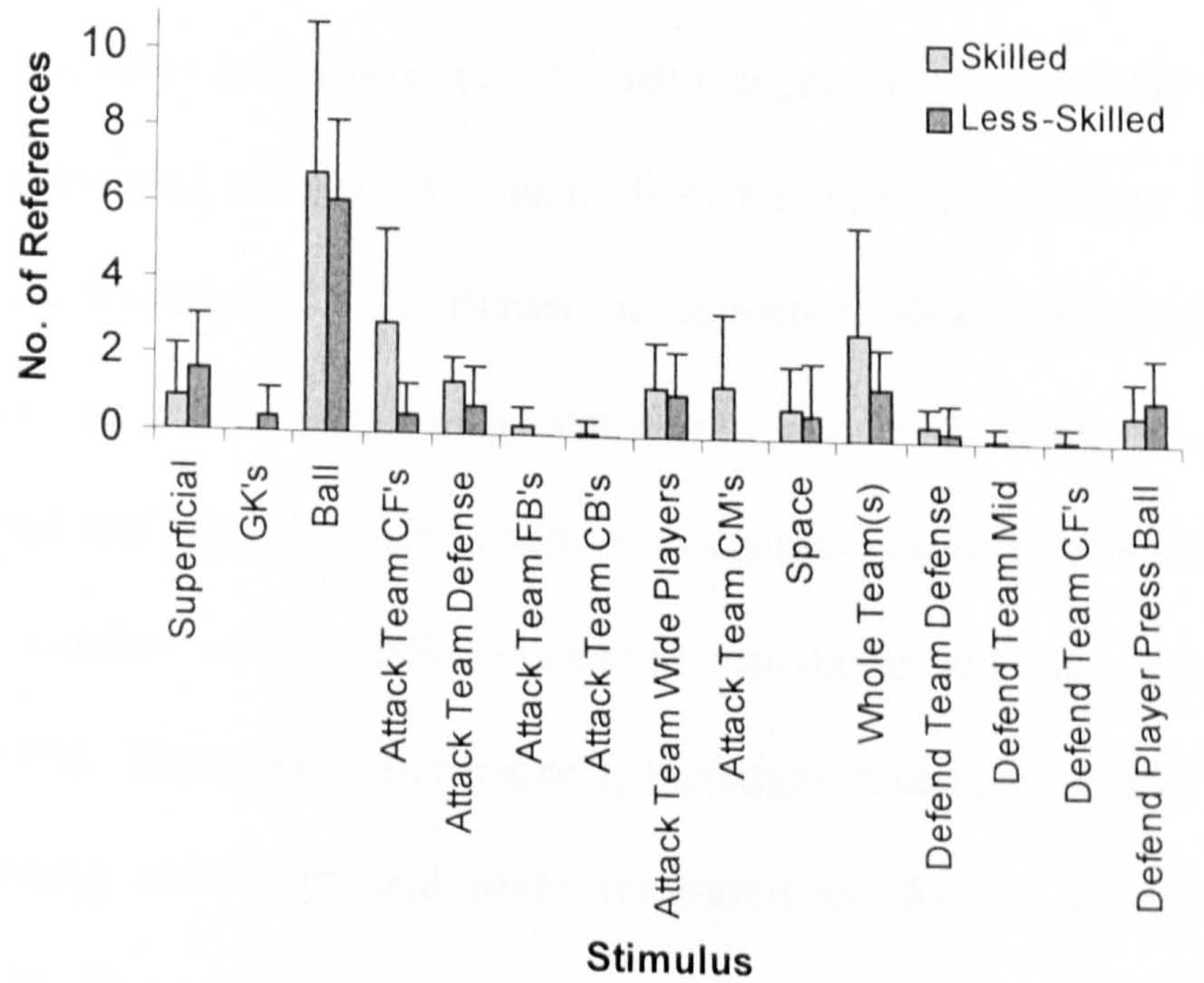
ANOVA revealed a significant main effect for skill, F (1, 17) = 9.89, p<.01, η_p^2 = .37, d =.29. Skilled participants (M = .47, SD = .87) verbalized more actions than less-skilled participants (M = .25, SD = .58). There was also a significant main effect for phase, F (1, 17) = 43.85, p<.001, η_p^2 = .72, d = .49. Participants made more action statements during the anticipation phase (M = .54, SD = .94) than during the recognition phase (M = .19, SD = .48). ANOVA also revealed a significant main effect for type of action, F (4.63, 78.74) = 6.90, p<.001, η_p^2 =.29. Bonferroni corrected pairwise comparisons showed that more verbalizations were made to the action category pass across defense than making space, and moving into wide space. More verbalizations were made to short passes than making space, and moving into wide space as well as the action categories gestures, directional passes, passes into space, turning, pressuring, movement into wide space, and marking. There were also more verbalizations made about attacking runs/movements off the ball than about the action categories, passes into space, and making space, all p's<.05. ANOVA showed there was a significant Phase x Action interaction, F (7.19, 122.14) = 3.99, p<.01, η_p^2 = .19. In the anticipation phase more action statements were made to short passes (M =1.79, SD =1.13 vs. M =.53, SD =.61) d = 1.39, and attacking runs/movements off the ball (M =.84, SD =1.12 vs. M =.37, SD =.60) d = .52, than when recognizing. To a slightly less pronounced extent this effect was also evident for long/aerial passes (M =.47, SD =1.02 vs. M =.11, SD =.32) d = .48, switching play (M =.63, SD =.90 vs. M =.21, SD =.42) d = .60, and collective movements (M =1.42, SD =1.74 vs. M =.37, SD =.76) d = .78. The Skill x Phase interaction narrowly failed to reach significance, F (1, 17) = 3.70, p =.07, η_p^2 =.18. There is a trend for skilled participants to make more action statements when anticipating (M =.70, SD =1.06), yet this is reduced when recognizing (M =.24, SD =.55), d = .54. The Action x Skill, and Skill x Action x Phase interactions were all not significant, F's = 1.91, and .74, and η_p^2 =.10, and .04 respectively, both p's >.05.

Stimuli

ANOVA revealed a significant main effect for phase, F (1, 17) = 36.68, p<.001, η_p^2 =.68, d =.36. More stimuli statements were made in the anticipation (M = 1.13, SD = 2.11) compared to recognition phase (M = .54, SD = 1.17). ANOVA also revealed a significant effect for type of stimulus, F (4.11, 69.79) = 26.95, η_p^2 =.61. Bonferroni corrected pairwise comparisons showed that more verbalizations were made about the stimulus category, ball/player in possession than all other stimulus categories. It was shown that more verbalizations were made to the stimulus, superficial features, than defending team midfield, and defending team central attackers. The stimulus categories, attacking team wide players, and whole collective team(s) were verbalized more than the stimulus categories, attacking team wide defenders, attacking team central defenders, defending team midfield, and defending team central attackers, for all comparisons, p<.05. The effect of skill narrowly failed to reach significance, F (1,

17) = 3.94, p =.06, η_p^2 =.19, d =.16. The trend showed that skilled participants (M = .97, SD = 1.93) reported a greater number of stimuli statements than less skilled (M = .70, SD = 1.40) participants. ANOVA showed a significant Skill x Stimuli x Phase interaction, F (5.29, 89.87) = 2.23, p<.05, η_p^2 =.12. When anticipating, skilled (M = 2.91, SD = 2.51) participants make significantly more statements referring to attacking team central attackers than their less-skilled counterparts (M = .5, SD = .76), d = 1.30, yet in the recognition phase there is no difference between the number of references to this feature by skilled (M = .64, SD = .67) and less-skilled (M = .5, SD = .76) participants, d = .20. Similarly, when anticipating there is no difference between skilled (M = 6.82, SD = 3.95) and less-skilled (M = 6.13, SD = 2.10) participants statements to the ball/player in possession, d = .22, yet when recognizing, skilled players (M = 3.73, SD = 2.45) make more statements to this feature than the less-skilled (M = 1.75, SD = .71) participants, d = 1.10. Skilled participants (M = 2.82, SD = 2.79) also made more statements to whole team(s) than less-skilled (M = 1.38, SD = 1.06) players when anticipating, d = .68, yet there was no difference between skilled (M = .91, SD = 1.22) and less-skilled (M = 1.0, SD = .93) participants in their statements to this feature when recognizing, d = .08. The interaction is illustrated in Figure 2a and b. The Phase x Stimuli interaction was also significant, F (5.29, 89.87) = 9.42, p<.001, η_p^2 =.36. The number of verbalizations about the ball and player in possession (M = 2.89, SD = 2.13 vs. M = 6.53, SD = 3.24), whole teams (M = .95, SD = 1.08 vs. M = 2.21, SD = 2.30), and attacking team central attackers (M = .58, SD = .69 vs. M = 1.89, SD = 2.28) was reduced when recognizing compared to anticipating, d's = 1.33, .70, and .78 respectively. The Phase x Skill, and Stimuli x

Skill interactions were not significant, F's = 1.76, and 1.50, and η_p^2 =.09, and .08 respectively, both p's >.05.



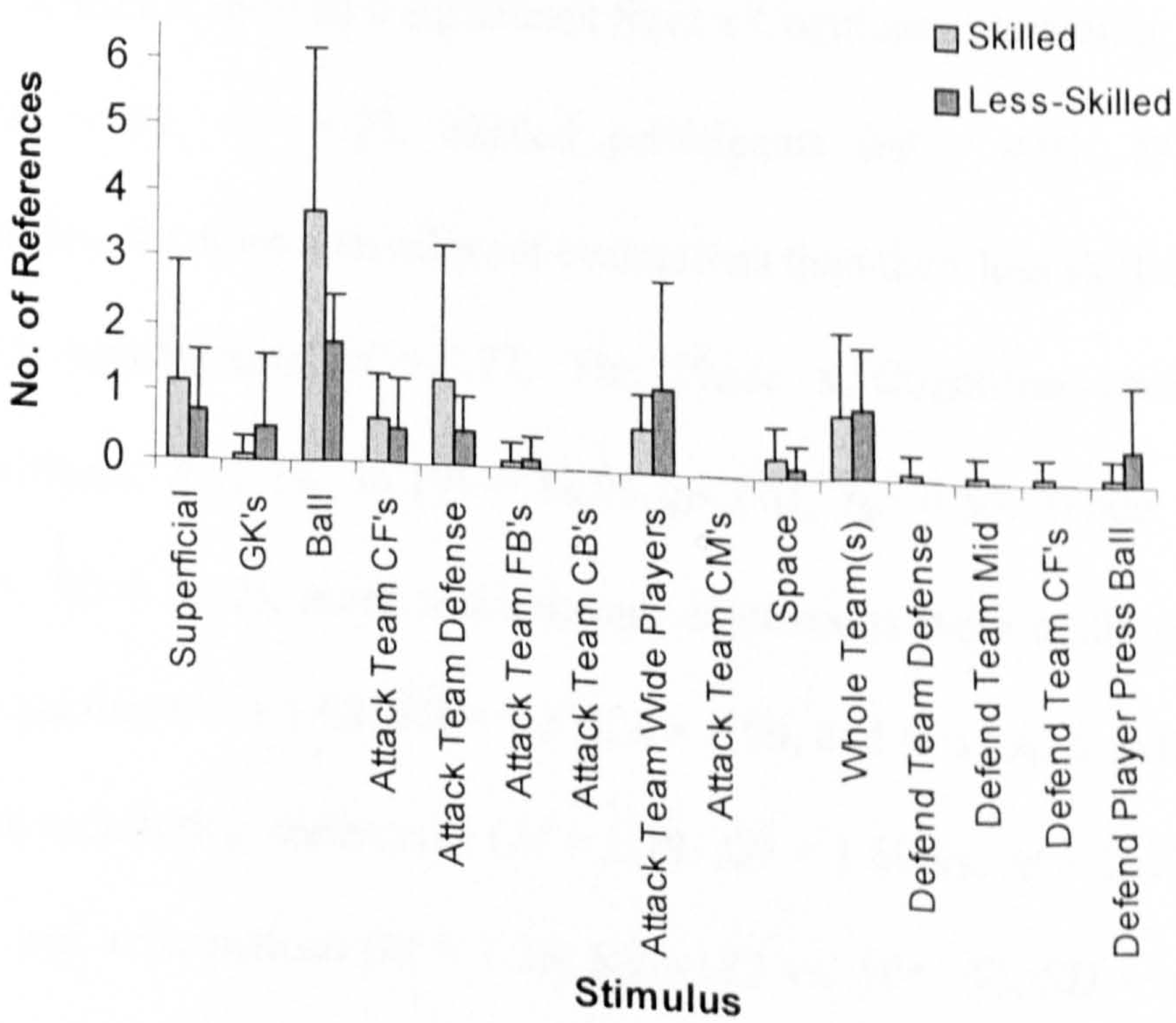


Figure 3.2. Skill x Stimuli x Phase interaction for a clip shown in film format during both a) anticipation and b) recognition phases (gk = goalkeeper; cf = central forward (attacker); fb = full back (wide defender); cb = central back (defender); cm = central midfielder).

Cognitions

ANOVA revealed a significant main effect for phase, F (1, 17) = 53.11, $p<.001$, η_p^2 =.76, d = .39. More cognitions were verbalized when anticipating (M = 1.19, SD = 2.27) compared to when recognizing (M = .52, SD = 1.05). ANOVA also revealed a significant main effect for type of cognition, F (2.61, 44.33) = 53.60, $p<.001$, η_p^2 =.76. Bonferroni corrected pairwise comparisons showed that more on pitch monitoring statements and task relevant evaluations were verbalized than all other cognition categories. There was no difference between the number of on pitch monitoring statements and task relevant evaluations ($p>.05$). There were also more anticipation statements made, rather than deep planning statements and irrelevant questions, for all significant comparisons, $p<.05$. There was no main effect for skill, F (1, 17) = 2.71, $p>.05$, η_p^2 =.14, d = .14. ANOVA showed a significant Skill x Cognition interaction, F (2.61, 44.33) = 5.19, $p<.01$, η_p^2 =.23. Skilled participants (M = 4.91, SD = 3.77) made significantly more task-relevant evaluations than their less skilled (M = 2.44, SD = 2.50) counterparts, d = .77. The Phase x Cognition interaction was also significant, F (2.13, 36.19) = 18.95, $p<.001$, η_p^2 =.53. When anticipating (M = 6.05, SD = 3.52), more task-relevant evaluations were made compared to when recognizing (M = 1.68, SD = 1.57), d = 1.60, and to a lesser extent so too were on pitch monitoring statements (M = 3.79, SD = 1.69 vs. M = 2.47, SD = 1.26), d = .89, and anticipations (M = 1.26, SD = .87 vs. M = .37, SD = .60), d = 1.19. The Skill x Phase x Cognition interaction was not significant, F (2.13, 36.19) = 2.50, $p>.05$, η_p^2 =.13. The Phase x Skill interaction was also not significant, F (1, 17) = 1.63, $p>.05$, η_p^2 =.76.

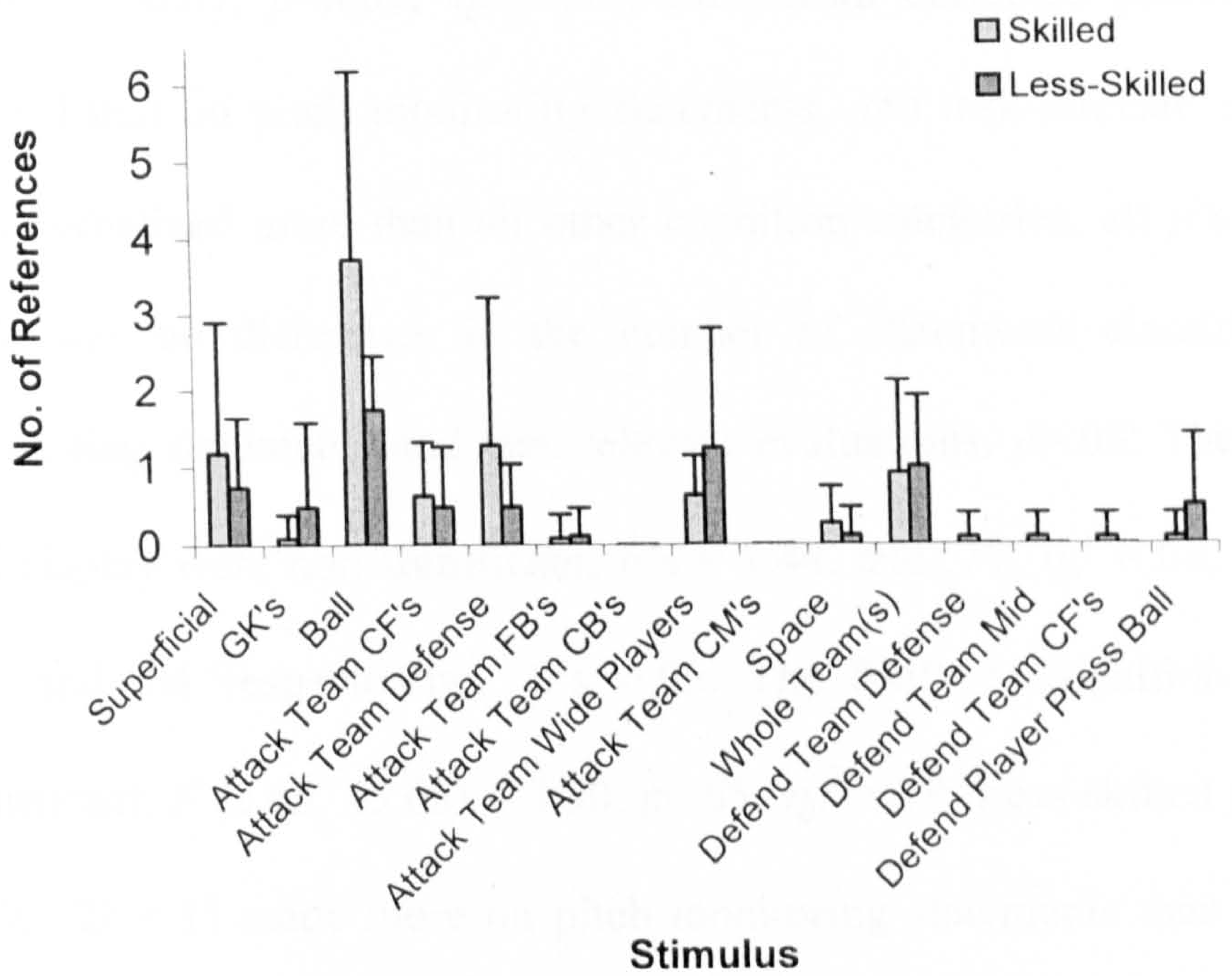
Analysis of a point light and film sequence during recognition.

Actions

ANOVA revealed a significant main effect for skill, F (1, 17) = 6.97, p<.05, η_p^2 =.29, d = .25. Skilled participants (M = .30, SD = .61) verbalized more actions then their less-skilled counterparts (M = .17, SD = .43). There was also a significant main effect for display, F (1, 17) = 8.53, p<.05, η_p^2 =.33, d = .17. More actions were verbalized under point-light (M = .28, SD = .60) than film (M = .19, SD = .48) format. ANOVA also showed a significant main effect for type of action, F (6.21, 105.64) = 7.40, p<.001, η_p^2 =.30. Bonferroni corrected pairwise comparisons showed that there were more verbalizations to passes across the defense than passes into space, shaping/posturing, turning, making space, pressuring, movement into central space, and movement into wide space. There were also more verbalizations to short passes than passes into space, shaping/posturing, and making space, all p's <.05. ANOVA also revealed a significant Skill x Action interaction, F (6.21, 105.64) = 2.17, p<.05, η_p^2 =.11. Skilled participants (M = .91, SD = .97) made significantly more verbalizations of attacking runs/movements off the ball than less-skilled (M = 0, SD = 0) participants, d = 1.33. The Display x Skill, Display x Action, and Display x Skill x Action interactions were all not significant, F's = .38, 1.68, and .98, and η_p^2 =.02, .09, and .05 respectively, all p's >.05.

Stimuli

ANOVA revealed a significant main effect for type of stimulus, F (3.44, 58.60), p<.001, η_p^2 =.61. Bonferroni corrected pairwise comparisons showed that there were more verbalizations to the ball/player in possession than all other stimulus categories. It also showed that there were more verbalizations to attacking team central attackers than attacking team central defenders, attacking team central midfielders, defending team midfielders, and defending team attackers. There were also more verbalizations to attacking team wide players than attacking team central defenders, attacking team central midfielders, defending team defense, defending team midfield, and defending team attackers, all p's <.05. There were no significant main effects for display or skill, F's = .00, and 1.21, η_p^2 =.00, and .07, and d = .01, and .08 respectively, both p's >.05. ANOVA also revealed the Skill x Display x Stimuli interaction was significant, F (3.78, 64.21), p<.05, η_p^2 =.16. Under point-light conditions, skilled (M = 3.55, SD = 2.54) and less-skilled (M = 4.5, SD = 2.62) participants showed no difference in verbalizations about the ball/player in possession, d = .37, yet in film format skilled (M = 3.73, SD = 2.45) participants made more verbalizations to the ball/player in possession than less-skilled (M = 1.75, SD = .71) counterparts, d = 1.10. Also, in film format, there is no difference in the number of verbalizations made to attacking team central attackers between skilled (M = .64, SD = .67) and less-skilled (M = .5, SD = .76) participants, d = .20. However, in point-light format, skilled participants (M = 1.55, SD = 1.13) made more verbalizations than less-skilled (M = .38, SD = .74), d = 1.22. The Skill x Stimuli x Display interaction is illustrated in Figures 2a and b. The Stimuli x Display interaction was also significant, F (3.78, 64.21), p<.05, η_p^2 =.18. More verbalizations were made about superficial features in film (M = 1, SD = 1.41) than in point-light (M = 0, SD = 0) format, d = 1. Also, more verbalizations were made about the ball/player in possession in point-light (M = 3.95, SD = 2.55) than in film format (M = 2.89, SD = 2.13), d = .45. The Skill x Display, and Skill x Stimuli interactions were not significant, F's = .67, and .91, and η_p^2 =.04, and .05 respectively, both p's >.05.



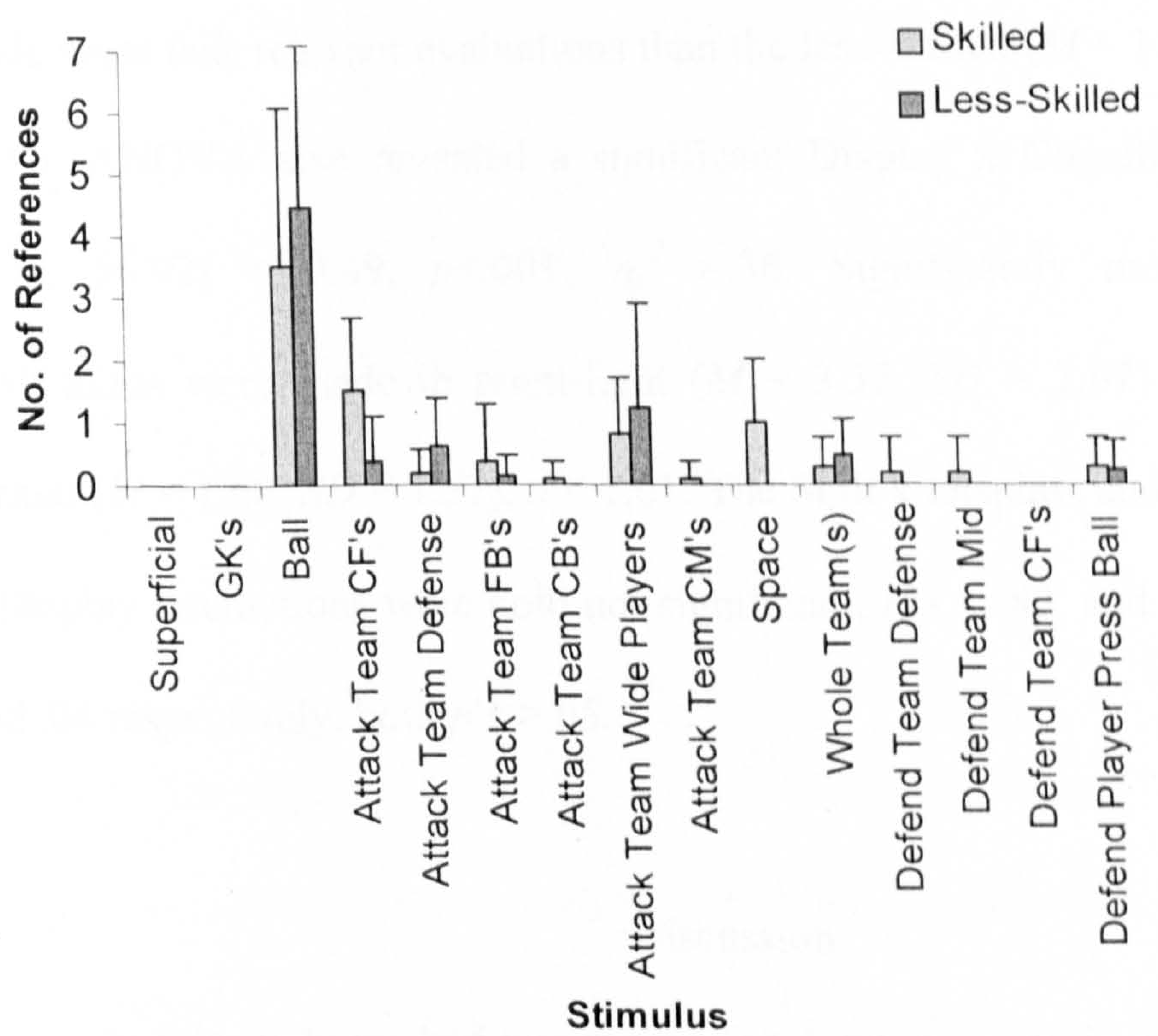


Figure 3.3. Skill x Stimuli x Display interaction for recognition of a a) film clip, and b) point light display clip (gk = goalkeeper; cf = central forward (attacker); fb = full back (wide defender); cb = central back (defender); cm = central midfielder).

Cognitions

ANOVA revealed a significant main effect for type of cognition, F (2.65, 45.06) = 50.01, p<.001, η_p^2 =.75. Bonferroni corrected pairwise comparisons showed that on pitch monitoring statements, and task-relevant evaluations were both verbalized more than all other cognition categories, all p's <.05. However, there was no difference in the number of statements classified as on pitch monitoring statements and task relevant evaluations, p>.05. The effects for skill and display were non-significant, F's = 1.44, and .74, η_p^2 =.08, and .04, and d = .10, and .04 respectively, p's >.05. The Skill x Cognition interaction was significant, F (2.65, 45.06) = 3.90, p<.05, η_p^2 =.19. Less-skilled participants (M = 2.69, SD = 1) made more on pitch monitoring statements than the skilled (M = 1.91, SD = 1.41), d = .64. However, skilled participants (M = 3.09, SD = 1.80) made more task relevant evaluations than the less-skilled (M = 1.69, SD = 1.45), d = .86. ANOVA also revealed a significant Display x Cognition interaction, F (3.35, 56.92) = 9.49, p<.001, η_p^2 =.36. Significantly more task relevant evaluations were made in point-light (M = 3.32, SD = 1.67) rather than film-format (M = 1.68, SD = 1.57), d = 1.01. The Skill x Display, and Skill x Cognition x Display interactions were both not significant, F's = .82, and .56, and η_p^2 =.00, and .04 respectively, both p's >.05.

Discussion

In this study we had two main aims. First, we examined the complexity of performers' memory representations and the role of LTWM in rapid, dynamic, and temporally demanding situations. These structures were examined during anticipation and recognition tasks, and while recognizing in both film and point-light display formats. Second, we attempted to identify the specific display features that were attended to and processed by skilled players to enable skilled anticipation and recognition. We expected that skilled performers would show superior anticipation accuracy and recognition sensitivity, and that skilled performers' recognition sensitivity would be enhanced under point-light display conditions, whereas for less-skilled participants a decrement in performance would be observed. We also predicted that skilled participants' retrospective verbal reports would support a LTWM account of expert memory, as highlighted by more complex internal representations as indicated by more stimuli and actions, as well as deeper cognitions (i.e., anticipations, options, and task relevant evaluations). If recognition is a valid measure of expert anticipation then this was predicted to be consistent across both tasks. We predicted that there would be no difference in the skilled participants' verbal reports when recognizing in point-light display compared to film format, whereas for less-skilled participants they were predicted to employ different strategies and a decrement in performance, signifying less refined cognitive representations. Finally, we predicted that the central attackers and their runs/movements when not in possession of the ball would be particularly important to skilled performers.

As predicted, skilled performers demonstrated superior anticipation accuracy than less-skilled participants. Also, in line with our predictions, skilled performers were more sensitive than their less-skilled counterparts in distinguishing previously seen from novel stimuli. Furthermore, there was no difference between the groups in terms of response bias. Skilled performers maintained their superior recognition sensitivity regardless of presentation format. Dittrich's (1999) proposal that skilled performers are able to process low level motion information and match this to a stored internal template is reinforced, providing further evidence that skilled performers process displays as a complex series of relationships. In a similar vein, support is provided for Ericsson and Kintsch's (1995) proposal that skilled performers' extensive practise allows them to encode, store, and index information in LTM in a manner that allows fast, and effective retrieval at a later time as isolated cues activate the associated retrieval structures. Next, we discuss how participants' retrospective verbal reports illustrate these retrieval structures and interpret the findings with reference to Ericsson and Kintsch's (1995) theory of long term working memory.

The retrospective verbal reports gathered from the skilled performers indicated that they were engaging complex memory representations. In both anticipation and recognition tasks skilled participants verbalized references to a greater number of actions and stimuli features than their less-skilled peers, indicating that when completing each task cues within the display stimulated richer and more complex retrieval structures. There was no difference in the number of cognitions (statement types) produced, showing that both skilled and less-skilled participants were able to adequately verbalize their thought processes. However, importantly the Skill x Cognition interaction demonstrated that there was a significant difference in the quality and depth of these cognitions, and that this effect was due to skilled performers reporting more task relevant evaluations when both anticipating and recognizing than less-skilled participants. It appears that skilled performers activate complex memory structures to represent displays when performing these tasks, but that in addition to enabling accurate anticipation and recognition these rich memory structures allow evaluation of events and potential outcomes, rather than merely observing and commenting on ongoing events. These findings support our predictions that skilled participants' thoughts would support a model that is consistent with the constructs of LTWM outlined by Ericsson and Kinstch (1995).

Although the results concur with the prediction that skilled players' decision-making strategies are governed by structures and processes consistent with LTWM, and this is so across anticipation and recognition tasks, other results question whether the recognition task engages these representations to the same extent as when anticipating. Ericsson and Lehmann (1996) first voiced concerns as to whether the recognition (and recall) paradigm was appropriate to capture the actual processes engaged during expert performance. They reviewed a number of studies that failed to report the expected skill difference (e.g., Schmidt & Boshuizen, 1993). It was argued that these methodologies, at best, only capture a process that is used incidentally during actual skilled performance and therefore may only represent a partial by-product of expertise (Ericsson & Smith, 1991).

Consistent with this argument, our results show that when recognizing participants verbalized fewer stimuli, actions, and cognitions compared to when they were asked to anticipate. In line with each of these main effects there are also significant interactions between stimuli, action, cognition, and phase. When anticipating, more statements were made to a broader range of stimuli features and actions, yet this effect is reduced when recognizing, suggesting that the recognition task does not encompass those processes engaged during anticipation that stimulate the use of highly complex memory retrieval structures. The possibility that during recognition the complex retrieval structures are stimulated differently is supported by the observation that when recognizing participants made fewer anticipation statements and task-relevant evaluations compared to when anticipating. These findings are inconsistent with the functions of LTWM outlined by Harris et al. (2006) that memory structures in LTWM support anticipation and evaluation of potential future events as well as developing structures 'on the go'. These findings contend that access to such complex representations is much reduced during recognition tasks and questions the extent to which such a task genuinely captures the processes engaged during actual performance and when performing more representative tasks (e.g., anticipation).

The Skill x Stimuli x Phase interaction suggests that skilled soccer players make more references to central attacking players and the whole team(s) when anticipating than less-skilled players, yet there was no difference between the skill groups when recognizing. In contrast, skilled players make more reference to the ball and player in possession when recognizing compared to when anticipating. As well as supporting the arguments of Ward, Ericsson, and Williams (in preparation) and Ericsson and Lehmann (1996) that recognition (and recall) tasks do not capture the processes determining skilled performance, they also mirror the findings of North et al. (submitted) using eye movement recordings. North et al. (submitted) reported that when anticipating skilled participants fixated their point-of-gaze toward central attacking players, yet this was reduced when recognizing and gaze was focused more toward the ball and player in possession of the ball. Taken together, these results provide strong evidence that an anticipation task may better capture the processes underpinning expert performance than a recognition task as indicated by changes in point-of-gaze across tasks and the complexity of cognitive representations governing each task as indicated by retrospective verbal reports. However, the proposal that recognition skill provides a measure of expert performance should not be dismissed completely. The findings that skilled participants report more stimuli and actions across both anticipation and recognition tasks, and the Skill x Cognition interaction demonstrating skilled performers verbalize more task relevant evaluations regardless of task, implies that during recognition skilled performers still activate and rely upon more complex retrieval structures than less-skilled participants. Also, North et al. (submitted) found a strong positive, yet non-significant, correlation between skilled anticipation and recognition, implying that expert performance and anticipation are complex concepts with many contributing factors. It is likely that recognition is a contributing factor to these, however as recent data suggests, its relative contribution may be less than first thought.

A comparison of the thought processes employed when viewing film and point-light displays supports the argument that skilled performers draw upon more complex memory structures during recognition than less-skilled participants. In addition to skilled soccer players referencing more action statements, indicating a more varied memory representation, the Skill x Cognition interaction demonstrated that skilled performers verbalized more task relevant evaluations, whereas less-skilled individuals made more 'on-pitch' monitoring statements when recognizing. Although the quality, and complexity of memory representation was somewhat impoverished when recognizing, skilled performers still engage structures that are more complex than those accessed by less-skilled participants, allowing situations, and potential outcomes to be considered and evaluated rather than merely monitored in their present state. Although the recognition task does not appear to call upon memory structures that are as complex as those used in anticipation, nevertheless the structures used by skilled participants and their apparent functions are still consistent with a LTWM account of expert behavior.

Thus far, we have suggested that when making recognition decisions skilled performers activate less complex memory representations than when completing a more representative task of domain performance (i.e., anticipation). However, the representations activated by skilled performers are still more complex than those engaged by less-skilled performers, and consistent with the functions outlined by LTWM. The retrospective verbal reports also provided evidence that despite being less complex, the representations engaged during recognition are structurally comparable to those activated for anticipation when we consider the specific stimuli features and action categories that participants make reference to across each task.

When anticipating and making recognition decisions the actions that thought processes refer to are predominated by 'short passes' and 'passes across defense'. Furthermore, the stimuli 'ball/player in possession' and 'wide players' were consistently verbalized across both tasks. To a lesser extent this was also true for central attacking players, although its relative contribution was much reduced during recognition, as evidenced in the Skill x Phase x Stimuli interaction (also see eye movement data from North et al., submitted). It can be seen that the representations engaged during the anticipation and recognition processes appear to be structurally similar, albeit somewhat less complex during recognition compared with anticipation.

We predicted that when comparing sequences recognized in point-light display and film format, skilled participants retrospective verbal reports would still be characterized by references to more stimuli, more actions, and deeper cognitions such as anticipation predictions, and task-relevant evaluations. We believe that skilled performers process displays as a series of complex relationships and the strategic information that these convey (see, Dittrich, 1999; Dittrich & Lea, 1994 Gentner & Markman, 1998; North et al., submitted; Williams et al., 2006). Consequently, viewing a display in point-light format where this information was maintained would not disrupt how skilled players perceive the scenes, the memory structures this would stimulate, and the thoughts that would be verbalized. In fact, the removal of additional information was predicted to highlight the critical information, facilitate the use of appropriate memory structures, and aid recognition performance in comparison to the film condition. In contrast, less-skilled players are less able to process this relational information and consequently, they rely upon more superficial and distinct features (Gentner & Markman, 1998; Williams et al., 2006). Thus, when this information is removed in point-light displays less-skilled participants were expected to verbalize fewer stimuli and actions and more 'on-pitch monitoring' cognitions. However, it should be noted that in addition to such superficial features as environmental conditions, film displays also portrayed players postural information, which too would not have been accessible in the subsequent point-light format.

The above predictions were initially supported by the Skill x Display x Stimuli interaction. In the film condition there was no difference between the skilled and less-skilled players in their references to central attackers. However, when viewing point-light displays skilled performers made more references than less-skilled players to central attackers. The importance of this feature is underlined further in the Skill x Action interaction comparing recognition of film and point-light display sequences where skilled players make significantly more reference to attacking runs/movements off the ball than less-skilled performers. Ward and Williams (2003) reported that to accurately capture the mechanisms underpinning expert performance it is best to use tasks that most accurately capture the demands of the 'real-world' situation (i.e. anticipation and situational assessment). We have already reported that when completing an anticipation task, retrospective verbal reports indicate the central attacking players to be critical to successful skilled performance. Using alternative methodologies, North et al. (submitted) and Williams et al. (2006) report similar conclusions. Therefore, we argue that for skilled performers, presenting scenarios using a point-light display highlights the critical information and facilitates their attention toward this feature. Such a notion is already favored in observational learning and rehabilitation settings where point light display presentations are used to teach or relearn skills (Hayes, Hodges, Scott, & Williams, in press). A potential future issue is whether such a technique may be successfully administered to train/develop perceptual-cognitive skill.

Contrary to our expectations point-light display conditions also stimulated more detailed and deeper thought processes for less-skilled as well as skilled performers on some measures. All participants referred to more actions in point-light display format and the Display x Cognition interaction showed that, regardless of skill, participants made more task relevant evaluations for point-light display sequences than those shown in film format. It appears that to a certain extent the point-light display format enabled even the less-skilled participants to engage more detailed memory structures and appraise the situation to a deeper and more meaningful level. Although this observation is hard to explain, it may be that removing such a large quantity of unnecessary information and maintaining what we believe to be the critical information allowed the less-skilled participants to be able to see 'the woods for the trees'. It must be highlighted too that skilled performers benefited more so than their less-skilled counterparts as they were able to decorate their verbalizations, and in turn their memory representations, with reference to display features that we have argued to be critical to skilled anticipation (see North et al., submitted; Williams et al., 2006).

Nevertheless, this is likely to be the reason why no Skill x Display interaction was observed in recognition sensitivity. Skilled performers performance improved dramatically when recognizing point-light display clips compared to film clips, however, surprisingly less-skilled participants also improved somewhat. Recognition performance improved for both participant groups in point-light conditions, although the improvement was greater for skilled performers.

In this paper we have shown that skilled performers have developed more complex memory structures than less-skilled performers that enable greater planning, task-relevant evaluations, and other such processes that are consistent with a LTWM memory account of performance. We argue that while recognition is still a valid measure of anticipation, it is likely only one contributing factor of many, and its contribution may be less than once thought. To accurately capture the factors underpinning expertise, the task must represent, as accurately as possible, the 'real-world' skill in which experts engage. In addition to providing evidence of the complex memory representations of skilled performers, we have provided strong evidence that central attacking players and their runs/movements off the ball are critical concepts within this structure that enables new information to be perceived and processed in a meaningful manner. Finally, we have provided evidence that skilled players process displays as a series of relationships between key display features, most notably the central attacking players positions, and their runs/movement when not in possession of the ball.

Chapter 4

Identifying the Critical Time Period for Information Extraction when Recognizing Sequences of Play

Abstract

The ability to recognize sequences of play is a predictor of anticipation skill in team ball games such as soccer. We aimed to identify the critical time period for information extraction when making such judgments. A perceptual recognition paradigm was employed. In the viewing phase, 31 professional youth soccer players viewed structured and unstructured match action sequences lasting 5 seconds each. During the subsequent recognition phase, players were randomly allocated to one of three conditions. In one condition the entire 5-second clip was viewed, whereas in the other conditions only the final 3 or 1 seconds were observed. The accuracy with which the information presented earlier was recognized was taken as a measure of performance. Superior performance was observed on the structured trials in the 3-second condition compared with the 1 and 5-second conditions. No differences were apparent on the unstructured trials. Patterns of play in team sports emerge over relatively short viewing periods and the presentation of additional contextual information may not facilitate recognition performance.

Key Words: recognition, constraint-attunement hypothesis, perception, temporal occlusion

In dynamic team ball games athletes have to perceive and process information in a selective and efficient manner, attending only to those features that facilitate performance and ignoring information that is redundant (Williams, Davids, & Williams, 1999). This ability is particularly important when performers must act under strict temporal constraint, as is typically the case in elite level sport. An important element of this skill is the ability to identify meaningful patterns or relationships between discrete display features. For example, in soccer, skilled players are better than their less-skilled counterparts at picking up important relational information between players when attempting to recognize evolving sequences of play (Williams, Hodges, North, & Barton, 2006). This ability to recognize familiar sequences of play has been identified as a strong predictor of anticipation skill (Williams & Davids, 1995). However, although there have been attempts to identify the critical time period for information extraction in relatively closed skill situations involving the tennis serve or soccer penalty kick (e.g., Tenenbaum, Levy-Kolker, Sade, Liebermann, & Lidor, 1996; Williams & Burwitz, 1993), this issue has not been examined using dynamic, open play situations in team sports. In this paper we bridge this gap in the literature by using a recognition paradigm and manipulating access to perceptual information so that participants must make judgements under varying temporal constraint.

The recognition paradigm was initially employed to analyse the ability of experts to make perceptual judgements in chess (Goldin, 1978, 1979). Allard, Graham, and Paarsalu (1980) subsequently extended this methodology to the domain of sport, and this study is reviewed in detail in Chapter 2. Evidence was provided that skilled performers perceive scenes as a function of relational information due to their advantage being limited to structured slides only. This pattern of findings for expert memory performance has been replicated across numerous domains such as field hockey (Starkes, 1987), American football (Garland &Barry, 1991), figure skating (Deakin &Allard, 1991), ballet (Starkes, Deakin, Lindley, & Crisp, 1987), and soccer (Williams & Davids, 1995).

The original proposal was that when viewing structured stimuli skilled performers chunked individual features into meaningful perceptual structures and then matched this information held in short term memory to an extensive array of perceptual structures stored in long term memory. The unstructured stimuli were proposed to contain no meaningful structures between display features, thereby making chunking difficult and removing any expert advantage (Chase & Simon, 1973). These proposals were eventually discounted because no decrements in performance were observed when interfering tasks were employed to prevent information being encoded in short-term memory (e.g., see Frey & Adesman, 1976). Ericsson and Kintsch (1995) subsequently developed the long term working memory (LTWM) model that proposes elite performers develop complex retrieval structures in long term memory as a consequence of prolonged deliberate practice and domain specific expertise. Those features present within structured sequences serve as cues that activate complex retrieval structures. The skilled performer can then judge the observed display in relation to the retrieval structure and make an accurate memory decision. When viewing unstructured displays, there are fewer, if any, features that can serve as cues to relevant retrieval structures in long term memory and consequently, memory performance suffers.

Thus far, few researchers have attempted to identify the specific information source(s) that players use when making recognition judgments (i.e., what?) or the critical time at which this information becomes available (i.e., when?). Williams, North, Hodges, and Barton (2006) provided more direct evidence that skilled performers detect similarity based upon structural relations within a display (for a detailed methodological review, see Chapter 2). A two-stage perceptual-recognition process was proposed to be involved combining low- and high-level cognitive processes. First, participants extract motion information, and temporal relationships between features, before matching this stimulus representation with an internal semantic concept or template (cf. Diderjean & Marméche, 2005; Dittrich, 1999; Gobet & Simon, 1996).

In contrast, no researchers have attempted to identify the critical time period for information extraction when attempting to recognize sequences of play in dynamic team sports such as soccer. Vicente and Wang (1998) argued that it is imperative for researchers to determine the important constraints that impact on expert memory. According to their constraint-attunement hypothesis, the ability to perceive structure is facilitated, and consequently expert performance is optimised, when there is greater access to higher order information (or constraints). For example, when stimuli are totally random there are no constraints on expert memory and therefore performance would be severely impaired. They argued that each domain will have a unique series of rules or constraints that allow the effective interpretation of scenes. When a scenario is rich in the amount of constraints provided then skilled memory performance should be high, whereas, in contrast, performance should be degraded when access to relevant informational constraints are reduced. An important task for researchers, outlined by Vicente and Wang (1998), is to identify the specific constraints that impact on skilled memory performance in each domain.

Although the constraint-attunement hypothesis makes no direct predictions regarding stimuli exposure time, it could be argued that the longer the exposure time, more contextual information is therefore presented and the more likely it is that expert memory will be facilitated. 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. It appears that knowledge of the strategic context of the ensuing action facilitates the decision making process. However, Vicente and Wang's (1998) proposal that the constraints to expert performance are unique to each problem domain, implies that the effect of increasing exposure time to more contextual information may not necessarily constrain expert memory performance in other domains. In soccer, for instance, there is evidence to suggest that playing patterns are discrete, highly complex, continually changing, and of varying temporal duration (Bloomfield, Jonsson, Polman, Houghlan, & O'Donoghue, 2005). A characteristic of soccer, and many other invasive team sports, is that it involves complex interactions between team-mates, opponents and the ball and consequently, discrete moments of order (structure) may be interspersed by periods of disorder or relatively random behaviour (Grehaigne, Bouthier, & David, 1997). The implication is that increasing exposure time to different sequences of play in soccer may not provide access to additional structural information, and therefore may not be a constraint to memory performance for such stimuli.

In support of the above argument, North and Williams (2006) inadvertently provided evidence to suggest that structure in soccer situations emerges in the final moments preceding a critical event. In an initial viewing phase, participants were required to anticipate the end outcome of dynamic sequences of play in soccer, as opposed to passively viewing these stimuli as would typically be the case when employing the recognition paradigm. The sequences each lasted 5 seconds and were occluded at the final frame preceding an attacking pass or attempt at goal. In the subsequent recognition phase, players were asked to decide quickly and accurately whether or not they had viewed each sequence previously. Although the skilled soccer players outperformed their less-skilled counterparts, the recognition accuracy scores were lower than expected based on reported literature. The instruction to respond quickly as well as accurately during recognition constrained players to make a decision early in the viewing sequence and potentially before the critical information relating to structure had evolved. When making such decisions the critical information, or structure, may emerge only in the final moments preceding the event to be anticipated (see Féry & Crognier, 2001).

In this paper we attempt to identify the important temporal constraint on expert memory in soccer. More specifically, we use a recognition paradigm to examine the critical time period for information extraction when identifying sequences of play. In an initial viewing phase, participants are presented with film clips involving structured and unstructured soccer sequences each 5 seconds in length. The structured sequences are occluded at the final frame prior to an attacking pass or attempt at goal. In a subsequent recognition phase, participants are required to decide whether or not they had seen these sequences in the earlier viewing phase. However, during the recognition phase skilled participants are required to view either the final 1-second of each sequence, the final 3 seconds, or the entire 5-second sequence. The accuracy with which the information presented earlier is recognized is taken as a measure of performance.

A viable prediction is that on the structured sequences recognition performance will be better at the longest exposure duration (i.e., 5 seconds) because the extended presentation facilitates memory performance by providing more contextual information or situational constraints (cf., Paull & Glencross, 1997; Vincente & Wang, 1998). An alternative hypothesis is that performance may be better at the shortest exposure duration (i.e., 1-second). For example, the analyses of Bloomfield et al. (2005) and Grehaigne et al. (1997) propose that soccer consists of a series of discrete periods of structure, interspersed with periods of chaotic behaviour or disorder. Similarly the observations of North et al. (2006) suggest that the crucial information underlying recognition performance arises only in the few moments preceding a critical event (e.g., an attacking pass or shot at goal). However, a final plausible interpretation is that performance will be best in the 3-second exposure condition. Skilled soccer players process relational information, and associated higher order strategic information, when attempting to recognize sequences of play (Williams et al., 2006) and consequently, the 1-second exposure duration may be too brief to facilitate effective recognition. In contrast, the periods of disorder that precede the emergence of order are unlikely to provide any meaningful information to facilitate recognition such that the extended viewing period in the 5-second condition is unlikely to provide any extra value. Moreover, the presentation of additional, non-relevant information in the 5-second condition compared with the

3-second condition may impair memory performance through proactive interference (Jonides & Nee, 2005). Finally, for unstructured sequences it is predicted that recognition performance will improve in line with the increase in exposure duration. The proposal is that unstructured sequences contain no apparent relational information between features and no critical event such as an attacking pass or shot at goal and consequently, performers may revert to processing these displays based upon discrete or superficial surface features. We predict therefore that as exposure time increases more surface features may be attended to and stored in memory for subsequent retrieval during the recognition phase.

Method

Participants

A total of 31 skilled players participated in this experiment (*M* age =16.4 years, *SD* = 1.8). The participants were all professional youth soccer players from two English Premier League Youth Academies. These players had been participating at this level for 9.5 years (*SD* = 2.05), and trained or played for an average of 9.24 hours per week (*SD* = 0.24). Participants provided informed consent and were free to withdraw from testing at any stage. The research was carried out according to the ethical guidelines of Liverpool John Moores University.

Test Film

Participants were presented with two separate test films, a viewing film and a recognition film. Each film contained both structured and unstructured sequences of play. The stimuli were taken from the same three Premier League matches as used in Chapter 2, but did not include any matches involving the clubs holding the registration of the participants. The filming location was the same as that outlined in Chapter 2. Three expert soccer coaches independently rated each sequence as structured or unstructured using a Likert-type scale from 0 to 10 (0 being completely unstructured, 10 being completely structured). Structured stimuli represented playing patterns that were representative of organized offensive sequences of play. Unstructured stimuli represented a breakdown in play with no apparent organization (e.g., players warming up, a break in play following an injury, players walking on or off the field of play). Sequences with a mean rating of 7 or above were classified as structured, and sequences with a mean rating of 3 or below were classified as unstructured. Sequences with a mean rating between 3 and 7 were discarded. The inter-observer agreement was 82.4%. A still frame from a typical structured sequence is shown in Figure 4.1.

Figure 4.1. The typical image observed on a structured trial.

The viewing film contained 40 sequences, 20 that were structured and 20 that were unstructured. In the viewing film all sequences lasted 5 seconds, with a 5-second inter-trial interval. The recognition film also contained 40 sequences, 20 that had been seen previously in the viewing phase and 20 that were novel. There were an equal proportion of structured and unstructured sequences. Three separate recognition films were produced. One test film showed the entire 5 seconds of each sequence, another was edited so that only the final 3 seconds of each sequence were presented, and the final recognition film was edited so that only the final 1-second of each sequence was shown. For each recognition film the same stimuli were used but edited to the appropriate length. The order of presentation of sequences was randomly selected, but kept constant across each recognition film and all participants.

Apparatus

The viewing and recognition films were played using a standard DVD player (Panasonic, DMR-E50, Osaka, Japan) sampling at 50 Hz, and front projected (Sharp, XG-NV2E, Manchester, UK) onto a 2.1-m x 1.5-m screen (Cinefold, Spiceland, IN). The recognition film clips were edited using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA).

Procedure

Participants 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 professional soccer matches showing either attacking patterns of play or breakdowns in play. Participants were informed that each clip lasted 5 seconds, and that clips showing attacking patterns of play would lead to either a pass into an offensive area or shot at goal, although the action would be occluded at the final moment before this event occurred. Participants were instructed to watch the clips as if viewing a televised soccer match.

Following presentation of the viewing film, there was a 10-minute break during which participants completed a detailed practice history questionnaire. Participants were then randomly assigned to one of the three recognition conditions and informed they would be presented with a second test film showing more soccer clips. The participants were informed that this film would contain some clips they had seen before and other clips that were novel, or the final 1 or 3 seconds of clips they had seen before, and the final 1 or 3 seconds of clips they had not. Participants were instructed to watch each clip for its entire duration and then make a recognition decision whether or not that clip had been presented previously in the viewing phase. Participants responded by placing a tick or cross in a box using a pen and paper response sheet provided. The participants all viewed the sequences in the viewing phase as a group, while each of the three sub-groups subsequently viewed the recognition sequences independently of the other two groups. Participants were randomly assigned to each of the three groups, although efforts were made to ensure that each group had a similar number of defenders, midfield players, and attackers. There was an inter-trial interval of 5 seconds.

Data Analysis

The response measure recognition accuracy (RA) was generated. Recognition accuracy was calculated as the number of correctly recognized scenarios divided by the total number of clips and multiplied by 100 to create a percentage accuracy score. The RA data was analyzed using a mixed design 2-way analysis of variance (ANOVA) in which the between participants factor was presentation time (1-second vs. 3 seconds vs. 5 seconds) and the within participants factor was structure (structured vs. unstructured). No violations of normality or homogeneity were noted in the data set. For all main effects and interactions, partial eta squared (η_p^2) values are provided as a measure of effect size, and where appropriate Cohen's *d* measures are also reported. When analyses indicated statistical significance, Tukey's multiple comparison tests were employed as follow-ups. The alpha level for significance was set at $p < .05$.

Results

ANOVA revealed a significant Structure x Presentation Time interaction, F (2, 28) = 4.58, $p < .05$, $\eta_p^2 = .25$. When viewing the unstructured sequences there was no difference in recognition performance across 1-second (M = 66%, SD = 5.2), 3 second (M = 62.7%, SD = 9), and 5-second (M = 62%, SD = 9.2) presentation times. However, on the structured sequences recognition performance was significantly more accurate for 3-second sequences (M = 72.7%, SD = 6.8) compared to 1-second (M = 62%, SD = 5.4) and 5-second (M = 63.3%, SD = 6) conditions. This is illustrated in Figure 4.2. There were no significant main effects for structure, F (1, 28) = 2.21, $p > .05$, $\eta_p^2 = .07$, or presentation time, F (2, 28) = 2.65, $p > .05$, $\eta_p^2 = .16$.

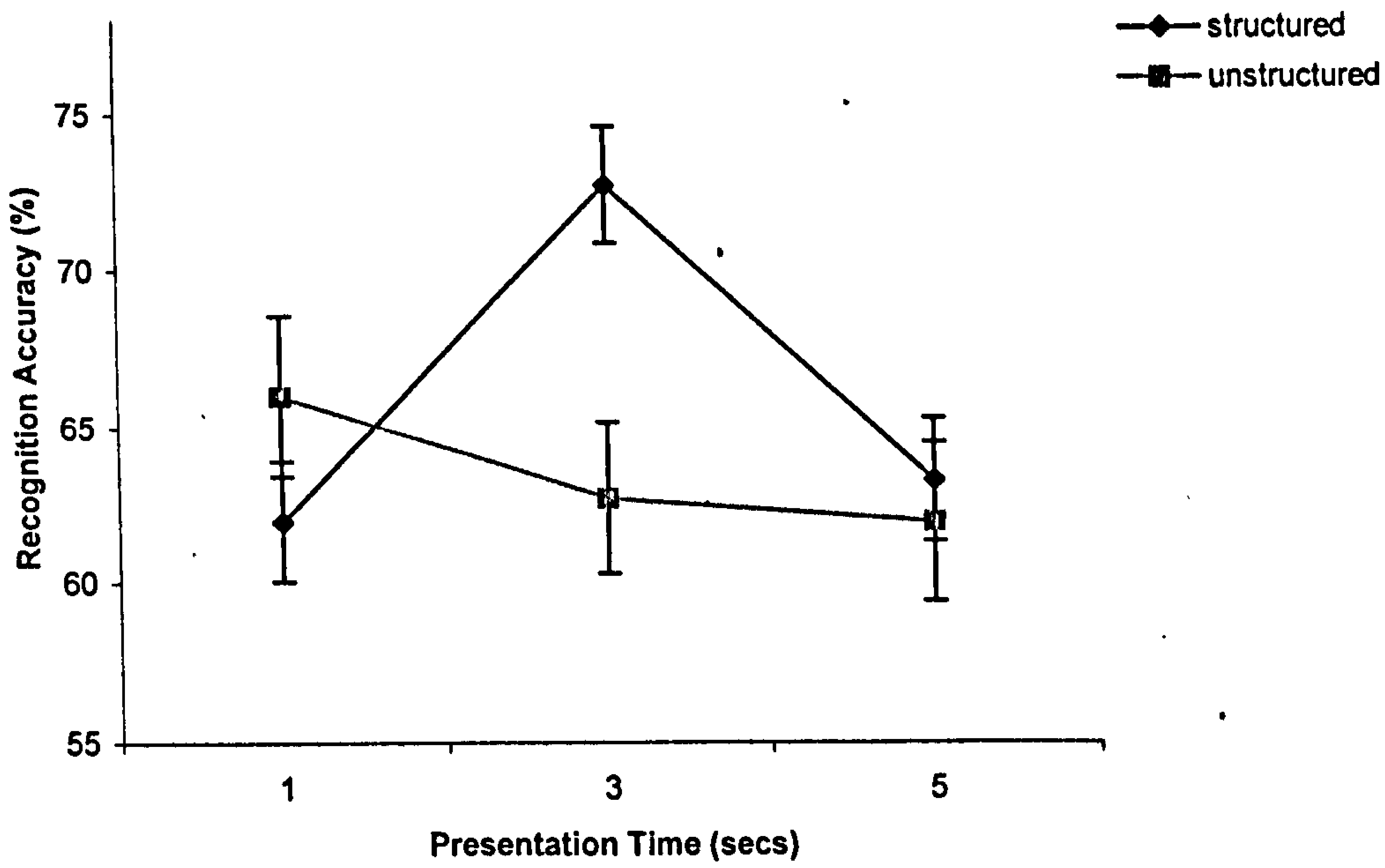


Figure 4.2. Mean (and SE) recognition accuracy scores for structured and unstructured sequences across the three viewing presentation times.

Discussion

The aim in this paper was to determine the critical time period for information extraction when attempting to recognize sequences of play in soccer. Although efforts have been made to identify the perceptual information underpinning such decisions, no researchers have attempted to determine when this information may be extracted from the display. We used a recognition paradigm and manipulated the duration of film sequences during the recognition phase in order to identify this critical time window. In an initial viewing phase, skilled soccer players were presented with action sequences lasting 5 seconds, while in a subsequent recognition phase participants viewed either the entire 5-second clip again or the final 3- or 1-second of each sequence. This research was novel and somewhat exploratory and consequently, we proposed several alternative hypotheses to explain which exposure duration would likely result in superior performance, particularly for the structured viewing sequences. Our predictions for the unstructured sequences were more concrete, with performance expected to improve at the longest exposure durations.

The skilled players recorded higher recognition accuracy scores on the structured sequences in the 3-second viewing condition rather than the 5- or 1-second condition. No significant differences were observed between the 1- and 5-second conditions. The finding that recognition performance for structured sequences is enhanced when limited to viewing only the final 3 seconds of an attacking sequence is important in understanding expert performance and anticipation in soccer. The results support the proposal that in relatively chaotic sports, such as soccer, structure only emerges at discrete moments preceding a critical event. The present research supports the conclusions derived from notational analysis that invasive sports like soccer involve a continually changing sequence of events in which order occasionally surfaces before descending into disorder once more (Grehaigne, et al., 1997). Our findings elaborate on this proposal by highlighting specifically that structure emerges during the final 1 to 3 seconds preceding a critical attacking event (e.g., shot at goal or penetrative pass).

It has already been established that when attempting to identify sequences of play in soccer skilled players' process the relational information between features and the associated higher order strategic information conveyed by these relations (Williams et al., 2006). Therefore, when attempting to recognise sequences under very brief exposure times, such as our 1-second condition, there is only limited time to encode the relevant relational information present within the display, constraining players to make recognition judgments based on more superficial surface features. An important issue is that when presented with short viewing sequences performers are constrained to rely on different perceptual-cognitive mechanisms than those they may typically employ when making recognition judgments. In contrast, the presentation of longer viewing sequences, as in the 5-second condition, does not facilitate recognition performance, presumably because no meaningful additional constraints are presented after the initial 3-second viewing period. Our data even suggest that this additional information may interfere with the recognition process. The potential absence of relevant relational information, or the presentation of additional or conflicting perceptual information in the 3- to 5-second window causes interference and impairs stimulus processing. The presentation of apparently non-relevant perceptual information increases the difficulties involved when attempting to process information that arises later in the sequence, namely the critical relational information, thereby impairing memory performance through proactive interference (Jonides & Nee, 2005). In support of this argument, Monsell (1978) showed that recognition accuracy decreased when people were required to wait before making a response, whereas in chess, Gobet and Simon (2000) reported that recognition performance does not improve when exposure durations longer than 3 seconds are employed.

Typically, researchers using the recognition paradigm have used stimuli with durations of 5 seconds or longer (e.g. Smeeton, Ward, & Williams 2004; Williams, et al., 2006) under the presumption that longer viewing sequences provide essential contextual information and facilitate recognition performance. However, our data suggest that the essential information resides within the relational information that emerges in the key moments prior to an event (cf. Féry

& Crognier, 2001). As a consequence, the reported literature on recognition performance in sport may be based upon a methodological design that interferes with the perception of structure. Similarly, there are potentially important implications for those interested in developing training programmes that enhance the ability to recognise sequences of play (Williams & Ward, 2003). An essential prerequisite for the development of such training programs may be the need to initially identify both the critical time window for information extraction prior (i.e., when?) as well as the key information that needs to be picked up (i.e., what?).

In contrast to our original prediction, performance did not differ across the three temporal conditions for the unstructured slides. We predicted that because these sequences are relatively devoid of structure, and no apparent critical event is present, there is no specific time window when critical structural information emerges and consequently, recognition may no longer be based upon identifying relational information, but rather on the pick-up of more superficial display features. The extended presentation time was predicted to allow participants more time to pick up and process relevant features, and therefore provide more constraints to the decision making process. However, the findings suggest that the additional viewing time does not impact on recognition accuracy for unstructured sequences. There were no differences in recognition accuracy across the three conditions, although interestingly all three groups performed at levels significantly better than chance. A more important observation perhaps is that the skilled players only reported higher accuracy scores on the structured compared with the unstructured sequences in the 3-second condition, thereby further reinforcing the argument that meaningful structure only emerges within the 1 to 3 second time window.

In conclusion, we have provided evidence that in continuous dynamic sports such as soccer 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. Consequently, as per the guidelines proposed by Vicente and Wang (1998) for studying expert memory, we have identified an important constraint on skilled perception and recognition performance in soccer. Although increased exposure time may provide a valid constraint for perception of structure in more rigidly organised and less continuous contexts such as American football, baseball, and chess, as well as in non-sporting domains such as law enforcement (e.g., see Harris et al., 2006), the present results suggest that for more chaotic activities such as soccer the brief exposure times preceding a critical event provides a critical constraint to capturing expert performance. Findings have implications for those interested in capturing effectively the nature of perceptual-cognitive expertise (see Williams & Ericsson, 2005) and in enhancing performance enhancement in sport.

Chapter 5

The Influence of Relative Motion and Positional Information on Perception of Structure

Abstract

The ability to recognize sequences of play is an important predictor of anticipation skill in soccer. We aimed to determine whether skilled performers process relative motion or positional information between features when recognizing sequences. Skilled and less skilled participants completed a stimulus recognition paradigm. After viewing a series of 3-second structured sequences representing either dynamic patterns or a static image sampled from the final frame of such a sequence, participants were shown a recognition film. The recognition film also contained a series of dynamic patterns and static images, some which had been presented in the earlier viewing phase and some that were novel. Participants made familiarity judgments and recognition accuracy was taken as a measure of performance. A Skill x Display interaction was observed. Skilled players were significantly more accurate when recognizing dynamic displays compared to static images, whereas less-skilled players showed no difference across display formats. The relational information that skilled players encode is the relative motion between display features rather than positional information.

Key Words: recognition, perception, relational information, expertise

Success in dynamic team sports, especially those where the performer must act under temporal constraint, is dependent upon the athlete attending to cues that facilitate performance while simultaneously disregarding non-relevant features (Williams, Davids, & Williams, 1999). In dynamic, team ball-games, where numerous features interact, this skill is characterized by the perception of patterns within the display. For example, by using point light displays, it has been reported that skilled soccer players are better than less-skilled players at perceiving relationships between players when recognizing sequences (Williams, Hodges, North, & Barton, 2006). This recognition performance has been reported to be an important predictor of anticipation skill (Williams & Davids, 1995).

Although there has been significant research investigating the key temporal period for information extraction in closed skill/one-on-one scenarios (e.g., Williams & Burwitz, 1993), there is a paucity of work addressing this issue using dynamic, open play situations in team sports. North and Williams (submitted) addressed this gap in the literature and reported that when making recognition judgments structure emerged in the final 3-seconds preceding a critical event (e.g. attacking pass, shot at goal). However, in the work by North and Williams (submitted), and that examining skilled perception and recognition using point light displays (Williams et al., 2006), it remains questionable whether skilled performers process relationships as a function of the relative motion between players or positional information based upon players' positions. In this paper we address this issue by using a recognition paradigm and manipulating access to perceptual information such that judgments are made in response to stimuli portraying either relative motion or positional information.

The recognition paradigm is rooted in cognitive psychology; it was initially employed to examine expert performance and memory in chess (see Goldin, 1978; 1979). As documented in earlier chapters, Allard, Graham, and Paarsalu (1980) were the first to apply the paradigm in the sporting domain, and reported a skill advantage for structured sequences only, a finding that has proven robust numerous sporting domains. Over time the methodology has been refined in order to better simulate the real-life demands of sporting competition by using dynamic film rather than static slides, and measuring speed as well as accuracy of response (see Williams & Davids, 1995).

It was initially theorized that skilled performers' advantage for structured stimuli was a consequence of being able to 'chunk' isolated features into meaningful structures. This information held in short term memory was proposed to be matched to an extensive library of similar structures held in long term memory. The unstructured stimuli were believed to contain no meaningful patterns or structure, therefore making 'chunking' impossible and negating any skill advantage (Chase & Simon, 1973). The 'chunking' theory of expert performance was challenged when it was found that skilled performance was still maintained despite the introduction of a secondary task to prevent encoding of information in short term memory (see Frey & Adesman, 1976). It appeared that skilled performers utilized structures in long term memory to encode and interpret information. In line with this Ericsson and Kintsch (1995) developed the long term working memory (LTWM) theory of expert performance. The theory proposes that as skilled performers acquire experience within their chosen domain they develop complex representations in long term memory termed 'retrieval structures'. When presented with structured patterns, certain features and their relationships act as retrieval cues that stimulate and bring the appropriate retrieval structure into consciousness. Once the retrieval structure has been activated the skilled performer is able to judge the presented stimulus against this information and make an accurate recognition judgment. However, for unstructured stimuli there is likely to be nothing within the display that could operate as a retrieval cue, and it is unlikely that skilled performers will have developed retrieval structures for such scenarios. Consequently, the skilled players' memory performance would suffer on unstructured sequences.

Only recently have researchers attempted to identify the specific features that skilled performers utilize to make successful recognition judgments as well as the temporal period during which this information emerges. In a series of experiments reviewed in Chapter 2, Williams et al. (2006) provided evidence that skilled soccer players process dynamic open displays as a function of relational information between display features, and that the relationships between central attacking features appear particularly pertinent to the process. Subsequent research using complimentary methodologies, such as eye movement recording and verbal protocol analysis, has reinforced the findings and conclusions reported by Williams et al. (2006; e.g., see, North, Williams, Hodges, Ward, & Ericsson, submitted). Skilled perception is believed to combine low-level and high-level processes. First, participants extract motion information, and temporal relationships between features, before matching this stimulus representation with an internal semantic concept or template (see, Didierjean & Marméche, 2005; Dittrich, 1999; Dittrich & Lea, 1994; Gobet & Simon, 1996). The notion of an internal semantic template is similar to the concept of a retrieval structure outlined by Ericsson and Kintsch (1995).

Recently, North and Williams (submitted) made a novel attempt to identify the critical time period for information extraction when attempting to recognize sequences of play in dynamic team sports such as soccer and provided additional evidence that skilled players perceive and process relationships to facilitate recognition. North and Williams (submitted) tried to identify the specific exposure time underpinning skilled performance. After presenting skilled participants with a viewing film containing a series of 5-second clips, recognition judgments were later made to one of three test films showing either the final 1-second, final 3-seconds, or entire 5-seconds of each sequence. Skilled participants' recognition accuracy was significantly superior for 3-second sequences compared to the 1 and 5-second conditions where there was no difference in recognition accuracy. In addition to providing evidence that in dynamic sports such as soccer structure emerges at brief discrete periods preceding critical events, further evidence is provided that skilled players utilize the relational information present within the display when making familiarity-based judgments. The explanation provided by North and Williams (submitted) for impaired performance on 1-second clips was that the brief exposure time was not sufficient to allow skilled performers to encode the meaningful relationships present within the display.

The literature reviewed provides strong evidence that skilled performers encode displays involving numerous features as a series of relationships. However, what remains unclear is whether these relationships are encoded through relative motion information or positional information. In the study by North and Williams (submitted) it is possible that the final 1-second contained the meaningful relationships, however the brief exposure time may have prohibited skilled participants from encoding this information. The additional information provided in the 3-second exposure condition enabled participants to encode the positions of extra elements and extract the critical relational information. Alternatively, if skilled performers encode relationships as relative motion between features then merely extending the presentation time of the image seen during the final 1-second would have no effect on recognition performance. The improved performance under the 3-second exposure condition would be due solely to the additional motion information provided, not merely due to the extended exposure duration.

In this paper we use a recognition paradigm to identify another constraint on expert memory in soccer. More specifically, we examined whether skilled soccer players perceive structural relationships as positions between features or relative motion between features. In an initial viewing phase participants are presented with a series of 3-second structured stimuli, some showing dynamic film footage, others showing static film footage. Dynamic sequences are occluded at the final frame prior to an attacking pass or attempt at goal. Static sequences present the final frame prior to an attacking pass or attempt at goal for the duration of the clip. In a later recognition phase participants are once more presented with a series of 3-second stimuli, both dynamic and static, some of which will have been presented during the earlier viewing film and others that will be novel. Participants are required to decide whether or not they had seen each of these sequences in the earlier viewing phase. The accuracy of participants' familiarity judgments is taken as a measure of performance.

We predicted that skilled performers would encode relative motion information to detect structure within the display as predicted by Dittrich and Lea

(1994). Dittrich and Lea (1994) showed that when observers were asked to detect meaningful motion within a series of dynamic elements, recognition performance was significantly impaired when the 'goal letter' toward which the 'target letter' was moving was occluded, implying the use of relative motion information when perceiving dynamic scenes. This meaningful motion is then judged in relation to an internal template or cognitive representation (Dittrich, 1999; Ericsson & Kintsch, 1995). We expected therefore that skilled participants' recognition performance would be more accurate when viewing dynamic relative to static stimuli. In contrast, we predicted that less-skilled performers would not utilize relative motion information when encoding a display. Although less-skilled participants may attempt to extract some relational information from the display, their lack of experience within the domain means that compared to skilled players they will have developed 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 distinctive surface features present within displays. We predict therefore that there would be no differences in performance across the two viewing conditions for the less-skilled performers. Regardless of presentation mode, participants have the same amount of time to encode any distinctive surface features that may be present.

We also predicted that skilled players' recognition performance would be more accurate for previously presented than novel sequences. The repetition priming effect phenomenon demonstrates superior performance when processing old vs. new items. Gymnastic judges were more accurate in their assessment of previously studied movements than novel actions (Ste-Marie, 1996; Ste-Marie & Lee, 1991). Furthermore, Zoudji and Thon (2003) report that in a soccer decision-making task only expert soccer players improved their response time to previously seen stimuli. For novel stimuli, both expert and novice soccer players' response times did not improve. Through extensive experience it is proposed that skilled participants are differentiated from those less-skilled by the contents and/or functioning of their memory for soccer specific information, and have developed skilled memory processes for the encoding and retrieval of such information (Ericsson & Kintsch, 1995). We therefore predict that initial exposure to attacking sequences would stimulate the appropriate memory structure representing this information. The earlier stimulation in long term memory of such processed items would then facilitate the priming effect when these stimuli are repeated in the recognition phase. Also, according to skilled memory theory, skilled players encode stimuli in association with retrieval cues, which when presented later facilitate the activation and retrieval of stimuli from long term memory (Ericsson & Kintsch, 1995). Given the use of structured stimuli only it is likely that some new stimuli may be structurally similar, yet different to the sequences presented earlier. As a consequence of this similarity certain features may stimulate the structures already activated, thus creating false memory and impaired recognition performance for new stimuli by skilled performers. Such false memory of similar yet different stimuli has already been demonstrated in the recognition of faces (Ishai & Yago, 2006) and paintings (Yago & Ishai, 2006). Less-skilled performers however are unable to use such strategies due to their relative lack of soccer specific knowledge and memory, and therefore recognition accuracy for less-skilled participants is predicted to the same for old and new stimuli.

Method

Participants

A total of 13 skilled and 10 less-skilled players participated. Skilled players (*M* age = 16.9 years, *SD* = 0.6) were all professional youth soccer players in England. These participants had been playing for 9.8 years (*SD* = 1.4), and trained or played for an average of 11.7 hours per week (*SD* = 1.4). In contrast, the less-skilled players (*M* age =23 years, *SD* = 1.8) only played soccer at a recreational level and had been participating for an average of 3.6 years (*SD* = 2.6), and trained or played for an average of 1 hour per week (*SD* = 1.6). Participants provided informed consent and were free to withdraw from testing at any stage. All participants reported normal or corrected to normal levels of visual function. The research was carried out according to the ethical guidelines of the institution.

Test Film

Participants were presented with two separate test films, a viewing film and a recognition film. Each film contained structured offensive sequences of play. The stimuli were taken from the same battery of clips used in Chapter 2, and did not include any matches involving the club holding the registration of the participants. The filming location was the same as that reported in Chapter 2. Three expert soccer coaches independently rated each sequence as structured or unstructured using a Likert-type scale from 0 to 10 (0 being completely unstructured, 10 being completely structured). Structured stimuli represented playing patterns that were representative of organized offensive sequences of play. Sequences with a mean rating of 7 or above were classified as structured. Sequences with a mean rating below 7 were discarded. The inter-observer agreement was 82.4%. A still frame from a typical structured sequence is shown in Figure 5.1.

Figure 5.1. A frame from a typical structured trial

The viewing film contained 60 sequences, 30 that were dynamic and 30 that were static. Dynamic clips showed a 3-second attacking sequence that was occluded at the point that an attacking pass or shot at goal was about to be made. Static clips showed the final frame as an attacking pass or shot was about to be made and displayed this for 3-seconds. In the viewing film there was a 3-second inter-trial interval. The recognition film also contained 60 sequences, 40 that had been seen previously in the viewing phase and 20 that were novel. Of the clips that had been presented previously, 20 were dynamic clips and 20 were static. During the recognition phase, sequences were presented in a random order that was kept constant across participants. In the recognition film the inter-trial interval was 5-

seconds to allow participants sufficient time to make a response and prepare for the next clip.

Apparatus

The viewing and recognition films were presented using a standard DVD player (Panasonic, DMR-E50, Osaka, Japan) sampling at 50 Hz and back projected (Sharp, XG-NV2E, Manchester, UK) onto a 9' x 12' screen (Cinefold, Spiceland, IN). The clips were edited to produce static clips using video editing software (Adobe Premiere, Adobe Systems Incorporated, San Jose, CA).

Procedure

Participants 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 professional soccer matches showing attacking patterns of play. Participants were informed that each clip lasted 3 seconds, and would show either a dynamic attacking pattern of play that would lead to either a pass into an offensive area or shot at goal, although the action would be occluded at the final moment before this event occurred, or a static image representing the final frame of such a sequence. Participants were instructed to watch the clips as if viewing a televised soccer match.

Following presentation of the viewing film, there was a 10-minute break during which participants completed a detailed practice history questionnaire. Participants were then informed that they would be asked to view a second series of clips, some which had been presented previously in the viewing film, and some that were novel. Participants were again instructed that some of the clips would be dynamic attacking sequences, whereas others would be static clips showing the final frame of an attacking pattern of play. Participants were instructed to watch each clip for its entire duration and then make a recognition decision whether or not that clip had been presented previously in the viewing film. Participants responded by placing a tick or cross in a box using a pen and paper response sheet provided. There was an inter-trial interval of 5 seconds.

Data Analysis

The response measure recognition accuracy (RA) was generated. Recognition accuracy was calculated as the number of correctly recognized scenarios divided by the total number of clips and multiplied by 100 to create a percentage accuracy score. The RA data was analyzed 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 were display (dynamic vs. static) and familiarity (seen previously vs. unseen). For all main effects and interactions, partial eta squared (η_p^2) values are provided as a measure of effect size, and where appropriate Cohen's *d* measures are also reported. The alpha level for significance was set at $p < .05$.

Results

ANOVA revealed a significant main effect for skill, $F(1, 21) = 4.01, p < .05, \eta_p^2 = .16, d = .87$. Skilled ($M = 56.6\%, SD = 6.6$) participants demonstrated greater recognition accuracy than less-skilled participants ($M = 52\%, SD = 3.6$). ANOVA also revealed a significant effect for display, $F(1, 21) = 19.22, p < .001, \eta_p^2 = .48, d = 1.07$. Participants' recognition performance was more accurate for dynamic ($M = 58.6\%, SD = 8.6$) than static clips ($M = 50.7\%, SD = 5.9$). There was a significant Skill x Display interaction, $F(1, 21) = 6.75, p < .05, \eta_p^2 = .24$. Less-skilled participants showed no difference in recognition accuracy across dynamic (M = 53.5%, SD = 7.2) and static (M = 50.5%, SD = 2.6) clips, d = .55. In contrast skilled participants were more accurate when recognizing dynamic (M = 62.5%, SD = 7.6) compared to static (M = 50.8%, SD = 7.7) clips, d = 1.53. The Skill x Display interaction is illustrated in Figure 5.2. A significant Skill x Familiarity interaction was also reported, F (1, 21) = 5.01, p <.05, η_p^2 = .19. Less-skilled participants showed no difference in response accuracy regardless of whether clips had been presented previously (M = 51%, SD = 5.3) or were novel (M = 53%, SD = 7.1), d = .32. However, skilled participants' recognition performance was more accurate for previously presented clips (M = 63.7%, SD = 9) than novel clips (M = 49.6%, SD = 14.8), d = 1.15. ANOVA also revealed a significant Display x Familiarity interaction, F (1, 21) = 8.5, p <.01, η_p^2 = .29. When responding to dynamic clips recognition performance is more accurate for clips that are novel (M = 62.6%, SD = 18.6) than seen previously (M = 54.6%, SD = 14.1), d = .48. In direct contrast, when responding to static clips recognition performance was more accurate for previously seen (M = 61.7%, SD = 13.9) than novel (M = 40.3%, SD = 19.4) clips, d = 1.27. The main effect for familiarity and the Skill x Display x Familiarity interaction were not significant, F's = 2.82, and .52, and η_p^2 = .12, and .02 respectively, both p's >.05.

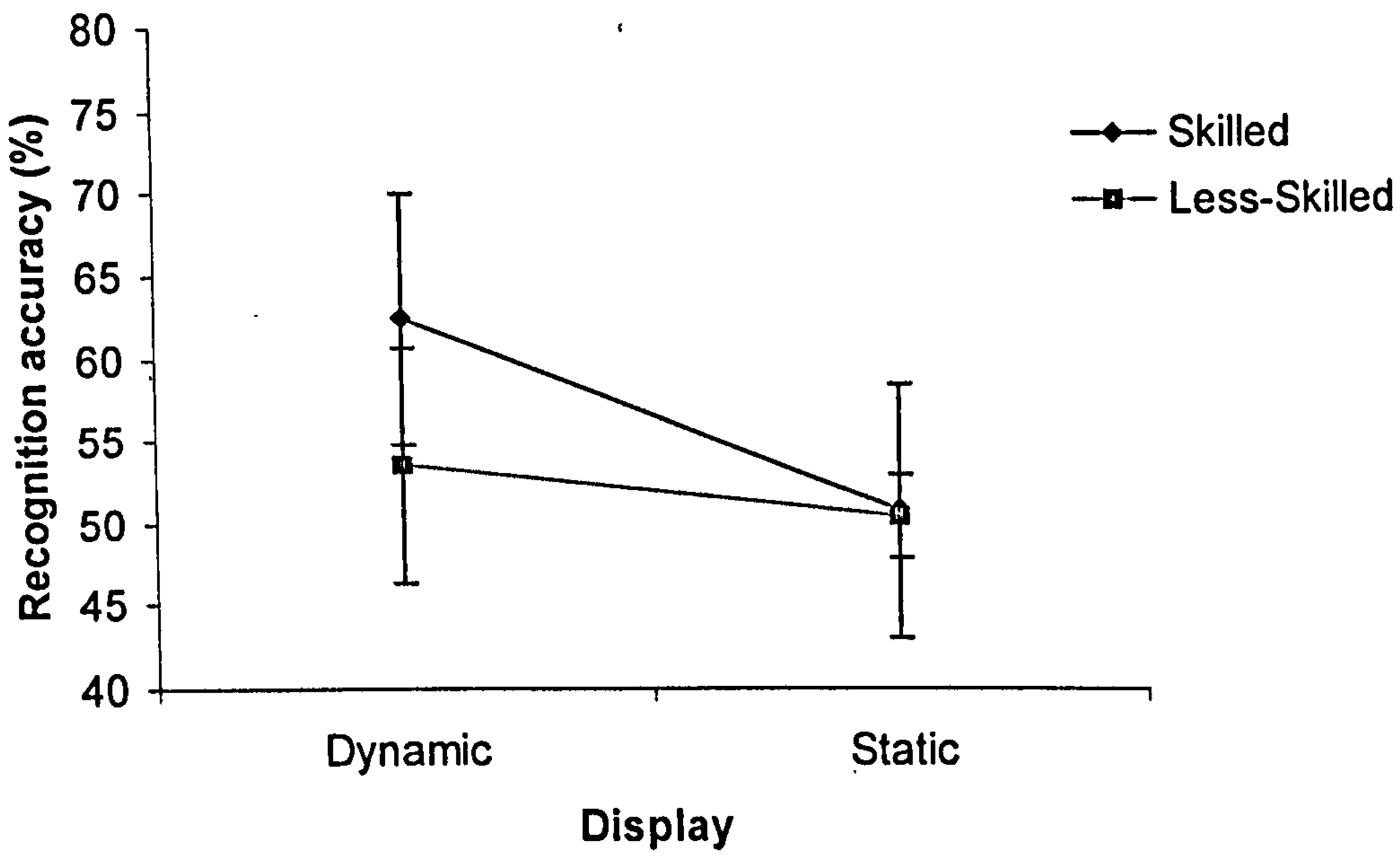


Figure 5.2. Skill x Display interaction for recognition accuracy (%)

Discussion

The aim of this paper was to determine whether skilled participants perceive structure within a display by encoding relative motion or positional information. Initial attempts have now been made to identify the specific display features underpinning skilled anticipation and recognition in soccer (North et al, submitted; Williams et al, 2006), and also the critical time period when this information emerges (North & Williams, submitted). Evidence has also been provided that skilled performers perceive and process displays involving numerous elements as relational information (North et al, submitted; Williams et al, 2006). However, whether these relationships are perceived via relative motion or positional information has not been investigated. Using a recognition paradigm, we presented participants with a series of structured displays, some that were novel and others that had been presented previously, either as dynamic playing patterns or as static images showing the final frame of an attacking sequence whilst controlling exposure duration to identify whether performers perceived relationships through motion or positional information. We predicted that skilled performers recognition performance would be more accurate for dynamic sequences than static slides, whereas less-skilled participants recognition accuracy would not differ between dynamic and static stimuli.

As predicted, skilled players demonstrated superior overall recognition accuracy than less-skilled players. The observed Skill x Display interaction was also as we predicted with skilled participants demonstrating more accurate recognition performance for dynamic compared to static stimuli, whereas less-skilled participants recognition accuracy showed no difference across these modes of presentation. The finding that skilled performers' recognition is most accurate, and distinguishable from less-skilled participants' performance for dynamic clips is important in helping to understand expert performance in soccer, and in identifying an additional constraint governing expertise within the domain (Vicente & Wang, 1998). The results provide evidence that skilled participants perceive relational information as a function of relative motion between display features.

The observed results can be interpreted by, and lend support to, existing perceptual and psychological theory. Dittrich and Lea (1994) provided evidence that when viewing displays it is relative motion that is crucial to perceive meaningful information. However, Vicente and Wang (1998) outline that each domain is likely to be characterized by a unique set of constraints underpinning expert performance in that field. This is demonstrated in the differential effects of increasing exposure time on performance in baseball (Paull & Glencross, 1997) and soccer (North & Williams, submitted). Furthermore, the research of Dittrich and Lea (1994) was conducted in a non-sporting context, prompting the need to clarify this issue in the domain of soccer. The findings are consistent with those of Dittrich and Lea (1994) and demonstrate that in soccer, skilled participants rely upon relative motion to extract the relational information between features and the associated higher order strategic information conveyed by these relations (see Williams et al., 2006). The use of relative motion information by skilled performers satisfies the initial low-level stage of processing outlined in Dittrich's (1999) interactive encoding model. In his two-stage model of skilled perception, skilled performers initially extract low-level relational information between features (specifically we now argue relative motion information). 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.

The results also support long term working memory theory (Ericsson & Kintsch, 1995). It proposes skilled performers' develop complex retrieval structures in long term memory as a function of experience. Once activated by a retrieval cue the appropriate retrieval structure is then employed to interpret and evaluate future situations and decide upon an appropriate response. We propose that the relational information provided by motion between key features acts as a retrieval cue to stimulate these complex retrieval structures in long term memory. Once activated the skilled performer can then judge the observed display in relation to the previously encountered stimuli represented in the retrieval structure and make an appropriate decision, thus accounting for the Skill x Display interaction and the superior recognition accuracy for skilled performers on dynamic displays only.

In addition to contributing and developing theoretical understanding of expert performance in soccer, the results have important implications for coaches and other practitioners working in an applied setting. When developing perceptual training programs, instead of focusing upon isolated players it may be essential that coaches highlight the relative motion between players and how this information is associated with particular outcomes. Video feedback is likely to be a useful aid to the coach when implementing this type of training. However, the coach is then faced with an important dilemma as to the most effective instructional methodology to provide this information, and this is an interesting and much needed avenue for future research (Jackson & Farrow, 2005).

The results also revealed a Skill x Familiarity interaction, which supported our prediction that skilled participants' recognition accuracy would be greater for clips seen previously than those that were novel. This supports the results of Zoudji and Thon (2003) that in a soccer decision-making task priming through exposure to previous material was only evidenced in a skilled population. The more accurate recognition for previously seen stimuli by skilled players supports the proposal put forward by Zoudji and Thon (2003) that prior exposure facilitates later retrieval by activating the appropriate structures in long term memory that can be accessed by the retrieval cues encoded alongside the stored information. However, a long term working memory account would predict that skilled players would demonstrate equally accurate recognition to new as old stimuli. We propose that as this study only used high structured stimuli, even those that were unseen contained many characteristics that were present in the previously presented stimuli. Therefore due to the high visual similarity across much of the stimuli, we argue that skilled participants perceived such novel scenes as previously presented stimuli as has been reported in recognition of faces (Ishai & Yago, 2006) and paintings (Yago & Ishai, 2006) and this was evidence in the Skill x Familiarity interaction.

In conclusion, we have provided evidence that in dynamic sporting domains involving interactions between numerous display features. Skilled performers encode structure by perceiving relational information between features through relative motion. As recommended by Vicente and Wang (1998) we have identified an important constraint to skilled performance in the domain of soccer. Our findings have important implications for those interested in identifying the mechanisms governing expertise (see Dittrich, 1999; Ericsson & Kintsch, 1995; Williams & Ericsson, 2005). In addition our findings, combined with other complimentary research, have important implications for those working in applied settings who wish to enhance sporting performance.

Chapter 6

Epilogue

Historically, researchers have debated whether performers who excel in their chosen domain do so as a function of an inherited genetic predisposition (e.g., Galton, 1869) or as a result of prolonged deliberate practice (e.g., Ericsson et al., 1993). Given contemporary literature it appears overly simplistic to attribute all skill differences to entirely innate factors (Janelle & Hillman, 2003). A less extreme stance posits that deliberate practice is a crucial ingredient in attaining expertise, yet it is influenced, or limited, by particular innate factors (e.g., Henry, 1957). Meanwhile, others still argue for a strictly 'nurturist' perspective believing that any individual is capable of expertise providing they engage in the necessary deliberate practice (for a more detailed review, see Howe, Davidson, & Sloboda, 1998). Therefore practice is a necessary component of expertise, however the debate is to whether practice alone is sufficient regardless of any other factors such as genetic influence.

Human beings are adaptive (Ericsson, 2003; Ericsson & Lehmann, 1996) and so changes occur to performers during practice. The adaptations that occur ensure that expert performers are differentiated from 'the crowd'. Researchers have identified certain physical (Pena et al., 1994), physiological (Jankovic et al., 1997), and anthropometric (Borms, 1996) measures that characterise elite populations within their specific sporting domain. However, given the increasingly homogenous nature of populations within highly skilled groups, such measures have proved not to be sufficiently sensitive to distinguish individual differences within highly skilled populations (Williams & Reilly, 2000). It is proposed that such characteristics may be less important in team sports than other factors relating to 'game knowledge', specifically perceptual-cognitive skills (Hoare & Warr, 2000; Williams & Reilly, 2000). Such a notion has been supported in recent research in soccer by Vaeyens et al. (in press) who report that within a skilled population differences in decision-making performance can be reliably predicted based upon such perceptual-cognitive indices as indicated by eye movement data.

The notions that deliberate practice is vital to the achievement of expertise and that the defining characteristics of expertise are fashioned through the adaptations that occur as a result of this practice have stimulated much research interest (for a soccer specific example, see Helsen, Stakes, & Hodges, 1998). Of particular interest is the idea that if the specific processes governing expert behaviours could be identified, it may be possible to develop appropriate training programmes to facilitate these adaptations without the need to engage in years of deliberate practice (Williams & Grant, 1999).

Researchers have therefore devoted significant periods of time to identify the specific features and display characteristics that expert performers utilise to enable their high level of performance. Using various methodological paradigms, such as eye movement recording, temporal occlusion, spatial occlusion, and point light displays, researchers have attempted to identify the critical performance cues that experts extract from a scene across an almost exhaustive cross-section of sporting domains. In team sports such as soccer and field hockey, despite a few notable exceptions (e.g. Williams et al., 1994), the overwhelming majority of this research has been conducted using relatively closed skill situations, or isolated micro-states of play (e.g., 1 vs.1, 3 vs. 3 in soccer). This research has proven valuable in identifying the important display cues underpinning skilled anticipation in these situations, and the information gleaned has been used successfully to train these skills (e.g., Williams, Ward, & Chapman, 2003).

However, team sports such as field hockey, soccer, and basketball are played as full sided competition, and despite considerable research being conducted using outcome measures, there have been limited attempts to identify the specific features/processes that underpin expert anticipation and decision-making in full sided, open play, dynamic, interactive sporting environments such as these.

The aim in this thesis was to address some of these issues raised above. Using the recognition paradigm, a technique that is reported to measure an important component of anticipation skill (Abernethy et al., 2005; Williams & Davids, 1995), through manipulations to stimulus material, the mechanisms underpinning skilled recognition and purportedly anticipation were investigated. Given the findings from studies involving the anticipation of point light displays portraying intra-individual kinematics (e.g., Ward, Williams, & Bennett, 2002), and studies involving perception of abstract scenes (e.g., Dittrich & Lea, 1994), it was predicted that skilled performers would perceive and process displays consisting of numerous interacting elements as a function of relational information between features and not on the basis of identifying isolated discrete display features. The issue of whether relationships between certain display features are more important for display structure to be encoded was also examined. Given the nature of the stimuli presented and previous research (Williams et al., 1994; Williams et al., 2006) it was hypothesised that the central attacking players relationships to one another, and potentially other features, would be especially important in portraying meaning and in essence giving a display structure. It was also predicted that in continuous, dynamic, interactive sports such as soccer, structure would emerge as discrete, isolated incidents preceding critical attacking events given the situational constraints of such an environment (Bloomfield et al., 2005; Grehaigne et al., 1997; Vicente & Wang, 1998). Following on from the prediction that skilled players would perceive and process displays as a series of relationships, it was predicted that these relationships would be conveyed as a function of relative motion as opposed to positional information. This was tested by conducting a recognition task, using dynamic patterns and static images sampled from the final frame of such sequences. Finally, the range of tasks and process tracing measures employed throughout the series of experiments meant that the degree of similarity between recognition and anticipation skill could be examined. The data from the process tracing measures during anticipation and recognition tasks were compared to test the degree of similarity between the strategies governing each skill, and also the outcome measures from anticipation and recognition tasks were correlated to test this also.

Summary of key findings

As detailed in Chapter 2, participants completed an anticipation task to film sequences involving dynamic, open play, 11 vs. 11 soccer scenarios, and were subsequently tested on an incidental recognition task. During recognition, participants had to decide whether each sequence had been presented during the earlier anticipation phase. In the recognition phase sequences were presented as either point-light display or film format. For point-light display clips, participants were instructed to decide whether each one represented a sequence presented previously, or represented a novel sequence. A head mounted eye movement registration system was worn throughout to record participants' point of gaze. In Chapter 2 several important issues were therefore addressed. First, comparing recognition performance and eye movement behaviours of skilled and less-skilled participants across film and point-light display sequences examined whether participants' perceive and process displays as a series of relationships or by identifying isolated, distinctive features. Second, by analysing skilled and less-skilled participants' point of gaze during the decision making process, the specific display features participants were using to inform their decisions could be identified. Finally, by comparing the eye movement behaviours of participants across the instruction to anticipate and later recognise allowed the extent to which the two tasks were governed by similar or different processing mechanisms (at least as identified by visual search) to be examined.

Skilled players demonstrated superior anticipation skill than less-skilled participants. Skilled players also demonstrated superior sensitivity in distinguishing between previously seen and novel clips than-less skilled participants. This superior sensitivity was evident for sequences presented in both film and point-light display format. The skilled participants fixated a wider range of locations than less-skilled participants, with this finding being maintained across stimuli presented in film and point-light display format. These findings suggest that skilled participants perceive and process these dynamic interactive environments as a series of relationships between display features. These relationships in turn are proposed to stimulate higher order strategic/tactical information (Gentner & Markman, 1997). Analysis of the eye movement behaviours revealed that skilled participants fixated on the central attacking players when not in possession of the ball more than less-skilled players across both anticipation and recognition tasks. There was no difference in fixations toward this feature when in possession of the ball. This finding was taken as evidence that the relationships between central attacking players provided the critical display information when making recognition judgments. It was suggested that skilled participants formulate structure by the relationships of the central attacking players relative to the ball, as skilled participants identified this feature earlier relative to sequence onset compared to less-skilled participants as indicated by point-of-gaze data. There was a moderate positive correlation between skilled players' anticipation and recognition performance implying the two skills are related to a degree. However, eye movement behaviours differed markedly across each task implying the contribution of recognition to anticipation skill may not be as great as previously implied (e.g., see Williams & Davids, 1995).

In Chapter 2 eye movement behaviours were recorded. Verbal reports are another method that can be used to look at the information players use during decision-making. Using eye movement data alone 'looking' and 'seeing' may be confounded as fixation location does not necessarily mean information extraction (Abernethy, 1988), and participants are able to relocate their focus of attention without shifting their point of gaze (Williams & Davids, 1998). Verbal reports do not confound either of these as there is no looking or seeing, just verbal reports of the thought processes engaged during decision-making. In Chapter 3 an attempt was made to elucidate participants' thought processes whilst engaged in decision making by collecting immediate retrospective verbal reports. This involved verbally detailing the series of thoughts that participants' were confident they had engaged in whilst presented with the stimulus and making either an anticipation or recognition judgment depending upon the task instruction at the time. Participants' verbalised their first thought and continued verbalising their sequence of thoughts through to the last. In Chapter 3 participants were again required to make anticipation decisions to filmed soccer scenarios showing 11 vs.

11, dynamic, open play situations. As in Chapter 2, an incidental recognition task was employed. During the recognition task, sequences were presented in either film or point-light display format. For the latter, participants had to judge whether the point light display clip represented a sequence presented earlier or a novel sequence that had not been presented previously. During both anticipation and recognition tasks, participants provided detailed retrospective verbal reports as to the thought processes they were engaged in when making either an anticipation or recognition judgment. Comparison of recognition performance across film and point-light display presentation formats allowed further examination of the issue of whether participants process scenes as a series of relationships or focus on distinctive, isolated features. By analysing the content of the verbal reports it was possible to gain an insight into the complexity of the processing of the image by participants, and also identify the characteristics that featured in the cognitions of participants when engaged in the decision making process. Comparing the verbal reports across anticipation and recognition tasks provided a further opportunity to assess similarities or differences in the processing mechanisms governing each task.

As with the findings from the first experiment, skilled participants showed superior anticipation performance compared to less-skilled players. Skilled participants were also more sensitive in distinguishing between previously seen from novel stimuli. Skilled participants maintained this enhanced sensitivity for sequences presented in both film and point-light display format. This finding provided further evidence that skilled participants process such sequences as a series of relationships between display features. Analysing the participants' verbal reports showed differences in the content of the thought processes as a function of skill. Skilled performers' verbal reports indicated thought processes that contained more varied action statements, more task-relevant evaluations, and reference to different and more varied stimuli than less-skilled participants. Generally speaking this finding implied that skilled participants were encoding scenes in a seemingly more rich and complex manner. Skilled participants made more reference to a whole team's general formation, supporting the notion that for skilled players displays are perceived as a series of relationships between features. Skilled participants also made more verbalisations regarding the movements of central attacking players, further implicating the role and importance of these specific features to skilled participants' perception of structure. Finally, the content of the verbal reports differed according to whether participants were engaged in an anticipation or recognition task implying that the processes underpinning each task are somewhat different. When recognising participants made reference to fewer stimuli and actions in their verbalisations compared to when anticipating. Further still, skilled players' verbal reports made less reference to central attacking players, and whole teams structure, whilst making more reference to the ball/player in possession when recognising compared to when anticipating.

In Chapter 2 (Experiment 1) evidence was inadvertently provided to suggest that in continuous, rapidly changing, dynamic sports such as soccer, structure may not develop as a continual function of time, but rather emerges in brief discrete segments immediately preceding important attacking plays. This issue was further explored in Chapter 4 using a temporal occlusion recognition paradigm. After viewing a series of 5-second dynamic action sequences, skilled participants completed an incidental recognition task under one of three conditions. Recognition decisions were made to either full-length 5-second.

sequences, or to sequences that had been edited so that either only the final second or last 3 seconds was presented. Skilled participants' recognition performance to structured sequences was significantly more accurate in the 3-second condition in comparison to the 1 and 5-second conditions. This finding suggests that in soccer structure emerges in brief isolated periods that precede important attacking events. Evidence has been provided that skilled participants' process displays as relational information between features. The 1-second condition was unlikely to provide sufficient time to allow participants to identify the appropriate features and their relationships. Therefore it was uncertain whether the enhanced recognition performance in the 3-second condition was due to the extra relative motion it provided or merely a function of time that allowed the relationships between the positions of features to be encoded regardless of motion information.

One related concept that necessitates discussion of these results relates to the phenomenon of proactive interference. Proactive interference is activity that occurs when additional information is presented prior to the information that is to be remembered and has been shown to be a limiting factor on memory when performers must retain discrete pieces of information (e.g., Stelmach, 1969). In view of the continuous, flowing nature of most sporting contexts its influence in a sport performance setting had not been investigated. In Chapter 4 it was found that the optimal exposure time for recognition performance was 3-seconds, providing evidence that in such contexts structure emerges in brief discrete periods just before the onset of an important attacking event. As presentation time was lengthened recognition performance deteriorated, suggesting that the preceding information represented an unrelated pattern that caused recognition performance to suffer, potentially as a function of proactive interference. This effect has demonstrated that even in continual flowing sporting contexts such as soccer, proactive interference occurs and is a potentially limiting factor to recognition performance. Arguably more importantly this finding questions whether the historical methodological framework against which the research into expert recognition has been conducted is partly flawed as it favours longer presentation times (5-seconds at least), believing this allows more contextual information to facilitate the interpretation of structure.

In Chapter 5 (Experiment 4), further attempts were made to determine whether relational information was perceived as a function of relative motion between features (i.e., dynamic) or the positional information between features (i.e., static). An incidental recognition paradigm was once more employed. Participants were first presented with a series of stimuli sampled from open play 11 vs. 11 soccer matches. Some stimuli showed dynamic sequences, others showed a static image representing the final frame of a dynamic attack.. Presentation time remained consistent for both dynamic and static stimuli. A second battery of clips was later presented containing both dynamic and static sequences, some that had been presented previously and some that were novel. For each stimulus participants were required to make a familiarity judgment. Skilled participants were more accurate at recognising sequences presented as dynamic displays, whereas they responded at the level of chance for those presented as static displays. This finding was taken as evidence that the relational information processed from structured displays is perceived specifically as a function of relative motion information between features.

Implications for theory

By attaching reflective markers to particular anatomical sites and removing all contextual information such that only the movement of these joint markers is visible it has been shown that humans are capable of judging an actors gender (Crawley, Good, Still, & Valenti, 2000), the weight a person is lifting (Shim, Carlton, & Kim, 2004), and the emotion expressed in a dance routine (Dittrich, Troscianco, Lea, & Morgan, 1996). Furthermore, expert sports performers are still able to accurately anticipate future event outcome from point-light displays of an opponent's actions (e.g., Abernethy & Parker, 1996; Shim & Carlton, 1999; Ward, Williams, & Bennett, 2002). It appears that for individual actions expert performers perceive critical information as relational kinematic information between certain joint locations, rather than one isolated unitary perceptual cue. In full-sided dynamic sporting environments where there are numerous features it had not been investigated whether skilled perception is dependent upon the extraction of relationships between critical features, or alternatively the identification of a specific cue in isolation. Gentner and Markman (1998) theorised that skilled players are likely to perceive scenes based upon structural relations and such higher order predicates such as tactical significance between the positions of display features, whereas less-skilled performers would rely upon lower level superficial features such as an isolated features location, or other potentially distinctive items, e.g., a body movement, environmental condition. In a non-sporting context, Dittrich and Lea (1994) demonstrated that perception of abstract scenes was dependent upon encoding relational information between otherwise meaningless features. Participants were required to detect meaningful motion between a series of letters on a monitor and were able to do this successfully. However, once the 'goal letter' toward which the 'target letter' was moving was occluded recognition performance was significantly impaired. Although the research in this thesis represents an initial attempt at investigating the perception of inter-individual relationships in a dynamic sporting context, it was expected that skilled participants would prioritise the relationships between features as a means to interpret the environment.

In Chapters 2 and 3 evidence was provided that skilled performers do indeed perceive environments that are characterised by interaction between numerous dynamic elements as a series of relationships between these features. Skilled participants' superior sensitivity in discriminating previously seen from novel scenes was maintained from film to point-light display format. The eye movement data recorded in Chapter 2 indicated that skilled participants prioritised the extraction of relational information between features to process scenes, as skilled participants fixated more disparate display areas, implying a processing strategy that sought to identify relations between various features. Furthermore, this effect was maintained across film and point-light display formats. In addition, the retrospective verbal reports collected in Chapter 3 supported these conclusions made on the basis of the eye movement data. The retrospective verbal reports of skilled participants contained references to a greater number of actions and stimuli features than less-skilled participants' reports. This finding was taken as an indication that skilled participants were perceiving and processing scenes in a more complex manner, whereas less-skilled participants were prioritising the identification of isolated superficial features.

Taken together, the findings support the theoretical proposition that skilled players perceive complex environments as a series of relationships between features. In contrast, less-skilled players rely upon the identification of distinctive superficial items (Didierjean & Marmeche, 2005; Gentner & Markman, 1997, 1998). The results also lend credence to the interactive encoding model of perception (Dittrich, 1999). This two-stage model proposes that individuals initially extract relational information from an environment, which is subsequently interpreted at a higher level by matching against an internal semantic concept formulated via experience. Given the relative lack of experience of less-skilled individuals, this second stage cannot be completed. Therefore one proposal is that less-skilled participants initially attempt to extract relationships from the display, then once they realise they are unable to interpret this information, they abandon this strategy in favour of a technique that involves simple identification of discrete features. An argument is proposed that the second stage outlined by Dittrich (1999) is overly simplistic, although this is discussed in more detail later.

Although skilled participants demonstrated superior recognition accuracy performance irrespective of presentation format in all experiments, both skilled and less-skilled participants suffered a decrement in recognition performance for point-light display sequences compared with film presentations. The encoding specificity principle theory (Tulving & Thomson, 1973) advocates that the greater the similarity between the context at encoding and retrieval the better the retention performance will be. Similarly, if task context is very different between encoding and retrieval then performance will suffer. This finding has been observed consistently (e.g., West & Craik, 2001; Yarbus, 1967). A modified viewpoint however argues that if task context differs, yet each task is underpinned by the same fundamental processing mechanism then performance will not be affected (Guynn, McDaniel, & Einstein, 2001; Nowinski & Dismukes, 2005). Recognition has been identified as a component of anticipation (see Williams & Davids, 1995) without ever identifying the specific mechanisms underpinning each activity. The eye movement behaviours provide evidence that each task is governed by quite different processing mechanisms as indicated by different visual search behaviours for each task. Therefore, when making recognition judgments to sequences represented as point-light displays in these experiments the task instruction is different (i.e. anticipation vs. recognition) as well as the presentation medium (i.e. film vs. point-light display) as all information other than players' positions and movements are removed, e.g., players' uniforms, stadium surroundings, environmental conditions, postural information. It is not surprising that retention performance suffered most for recognition of point-light display sequences. In considering the encoding specificity principle the importance of specificity not only for task context, but also presentation context was highlighted.

As outlined earlier, the second stage of Dittrich's (1999) interactive encoding model argues for a matching process between the currently processed environment and stored semantic concepts/templates. The 'chunking' (Chase & Simon, 1973; Miller, 1956) and template matching (Gobet & Simon, 1996) theories of expert performance outline similar mechanisms in their accounts of expert memory (i.e., a simple matching of the present situation to a past experience and an appropriate response produced). An alternative account was provided in Ericsson and Kintsch's (1995) long term working memory theory. This model contends that the performer is not a passive bystander in the decision making process as appears in the simple matching accounts, but rather plays an active role in the process. According to long term working memory theory retrieval cues within the environment activate complex retrieval structures stored in long term memory. Once activated these structures do not simply prescribe a predetermined decision, but rather allow the performer to consider several alternative courses of action, consider the potential consequences of each of these, and make appropriate evaluations before deciding on an appropriate response.

As detailed in Chapter 3, the retrospective verbal reports revealed that although there were no differences in the number of cognitions reported by skilled and less-skilled participants, these cognitions differed significantly in content. Skilled participants made more task relevant evaluations throughout, making judgments to ongoing events, but also making appraisals of potential future events and their outcomes. Such processes are incompatible with simplistic matching accounts of expert performance (e.g., Chase & Simon, 1973; Gobet & Simon, 1996; Miller, 1956), yet are consistent within the proposals of long term working memory theory (Ericsson & Kintsch, 1995).

The second stage of Dittrich's (1999) interactive encoding model that proposes a simple matching mechanism appears overly simplistic in light of the verbal report data. Although the interactive encoding model and long term working memory theory were developed based on existing literature focusing on perception and cognition respectively, the two theories could be viewed as complimentary. When combined, these theories provide a more encompassing account of expert performance in view of the current results concerning anticipation and recognition performance in soccer. Ericsson and Kintsch's (1995) long term working memory theory proposes that skilled participants identify retrieval cues within the display. The low level processing stage of the interactive encoding model and evidence provided in Chapters 2 and 3 suggests that dynamic, relational information between features acts as an important retrieval cue. Specifically in the present context the eye movement behaviours (Chapter 2) and retrospective verbal reports (Chapter 3) lead to the suggestion that it is the relationships between central attacking players that act as the retrieval cues. Furthermore, evidence provided in Chapter 5 would lead it to be proposed that it is the relative motion between these features that is important, and that relative motion between central attacking players acts as a retrieval cue to stimulate the appropriate retrieval structure stored in long term memory. This retrieval structure is analogous to the internal semantic concept/template outlined during the higher order processing of Dittrich's (1999) interactive encoding model. However, unlike Dittrich's (1999) model, processing does not stop at this point. Rather, the activation of the structure causes the performer to engage in active cognition, evaluating the environment and considering alternative courses of action, as outlined in long term working memory theory (Ericsson & Kintsch, 1995).

Implications for practice and considerations for future research

Performers' level of 'game knowledge' and ability to 'read the game' are perhaps some of the most important skills to allow players' to identify the movements of opponents or opposing teams early in their production, particularly in fast ball sports and team ball games (Hoare & Warr, 2000). In this thesis several experiments have been reported with the aim of identifying both the general processing mechanisms and the specific features that dictate the ability of skilled players to anticipate and recognise attacking patterns of play. Once important factors are identified that contribute to improved performance the tendency is to develop appropriate training programmes such that these properties can be nurtured and developed. This template is evidenced in the fields of nutrition

(Hanley, Tipton, & Millard-Stafford, 2006) and physical conditioning (Gamble, 2006) amongst others. A pertinent question to ask therefore is can an appropriate training programme be formulated to develop perceptual skill based on features and characteristics of skilled performance highlighted in this thesis?

Given that this thesis represents a novel programme of work attempting to identify the cues used for anticipation and recognition in open, full-sided, dynamic scenarios, it is not surprising that little research has been conducted to train recognition skill. Christina, Barresi, and Shaffner (1990) reported one rare exception although this technique involved simple repeated exposure rather than any instructional technique designed to highlight specific cues. If a perceptual training intervention were developed following on from the findings reported within this thesis the researchers would need to decide upon an appropriate instructional methodology used to highlight the important cues. Traditional instruction usually involves explicit instruction, although guided discovery or discovery learning methods have been used (for reviews see, Jackson & Farrow, 2005; Williams & Grant, 1999). The aim is to assist the performer in adopting the signature perceptual behaviours shown by those exceptionally skilful in anticipating and recognising. However, a concern is that while it may be possible to train participants to express these surface perceptual behaviours, it may not be mirrored by an equivalent development of the deeper cognitions and relations that underlie such perceptual characteristics and are equally, if not more, important to skilled performance (Ericsson & Chase, 1982; Ericsson & Harris, 1990). The collection of verbal reports, as detailed in Chapter 3, following a perceptually based training program would appear vital in addressing this issue by helping discover if any change in perceptual behaviour is accompanied by a development of the appropriate cognitions. It may also be useful to train a second group of participants to verbalise the cognitions of skilled participants (using information gleaned from Chapter 3) and examine its effect on performance and perceptual characteristics. Such an investigation would allow a weighted comparison between the relative importance of perception and cognition to expert performance.

The strength of the findings related to the encoding specificity principle (Tulving & Thompson, 1973) should also be considered by practitioners attempting to enhance decision making in applied settings. Based on the findings from this thesis and their grounding in principles of encoding and retrieval, and to satisfy the need for specificity of practice (Henry, 1968), the traditional approach of using video simulations to relay material (Williams et al., 2003) may not be the most appropriate. To satisfy these important theoretical constructs it may be better to develop training 'drills' where a series of players act as opponents and simulate pre-arranged attacking patterns. As in a game situation the defenders task is to 'read' the situation and attempt to intercept accordingly. As well as maintaining high similarity between encoding and retrieval contexts, and ensuring a high specificity of practice relative to the performance setting, using such a strategy would have other benefits also. By requiring participants to make actual bodily responses it would ensure that the need to couple perception and action (Goodale & Milner, 1992; Milner & Goodale, 1995) is satisfied. The use of 'live' actors would ensure a degree of variability from one trial to the next that would be beneficial in developing the adaptability of skilled performance required by expert performers, a need that is particularly highlighted in open sports such as soccer. However, the use of video feedback, and other such simulation should not be completely dismissed. A recent study by Williams, Ward, and Chapman (2003) demonstrated that highlighting key performance cues through video simulation resulted in improved anticipation of hockey goalkeepers that was transferred to the field setting as well as being evidenced in the laboratory.

The finding that proactive interference is a limiting factor to recognition performance (Chapter 4) could potentially be exploited in attacking scenarios. Coaches may wish to instruct their team to act out a number of 'dummy' patterns before finally employing a penetrative sequence. The presentation of additional associated information prior to the actual information to be acted upon will negatively affect the opponents' ability to retrieve the correct action from memory (Jonides & Nee, 2005), and will be exacerbated further if these earlier sequences are structurally similar to that to be acted upon (Smyth & Pendleton, 1990).

In Chapters 2 and 3 evidence was provided that the processes involved in recognition are not identical to those governing anticipation. Further still, it may well be that recognition is not *the* decisive contributory factor to anticipation. However, the positive correlation trend between anticipation and recognition in Chapter 2, the reliable differentiation between skilled and less-skilled performers on recognition tests, and the maintenance of certain perceptual and cognitive characteristics identified in Chapters 2 and 3 across tasks, means that recognition must certainly be considered as an important component of anticipation. It is already accepted that expertise itself is multi-factorial in nature (Reilly, Williams, Nevill, & Franks, 2000). It is likely too that anticipation is a complex concept with multiple contributory factors. Evidence has been provided that one such contributory factor is recognition. Therefore, any talent identification programme testing perceptual cognitive skill needs to bear this in mind. Tests measuring recognition could be conducted on an array of performers to identify those who perform below par on this measure, or alternatively coaches may identify performers they feel are lacking in 'game knowledge' or 'decision making skills'. Using the data collected in this thesis perceptual training programs could then be developed to attempt to improve this measure, and hopefully in turn anticipation in match scenarios. Given the likely multi-factorial nature of anticipation it is recommended that future research investigate the relative contributions of other potential determining factors such as recall, situational probabilities, advance cue utilisation, and visual search strategy. Such a collection of knowledge would allow a multi-factorial battery of perceptual-cognitive tests to be developed, with more knowledge of the relative contributions of each measure to anticipation, and increase the confidence with which it possible to measure perceptual-cognitive skill.

Conclusion

In conclusion, the experiments reported in this thesis have provided evidence of both the broad processing strategies, and specific display features, used to anticipate and recognise patterns of play in full sided, open play, dynamic soccer environments. The extent to which recognition contributes to anticipation skill was also examined. The thesis has provided evidence that skilled players interpret scenes through relational information between display features (players) as opposed to identifying isolated features. It is motion information rather than simply positional information that is critical in perceiving these relationships. Furthermore, it is the relational information conveyed by the movements of central attacking players that is the basis for skilled players' perceptual-cognitive skill. The structure perceived by skilled players emerges briefly in the immediate moments preceding an attacking event. The findings presented in the thesis have relevance both theoretically and practically and have opened avenues for future research.

Chapter 7

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