Blowing the Whistle on Umpire Decision Making: Investigating the Cognitive and Perceptual Correlates of Decision Making Accuracy in Netball Officials.

Alana M. Coombe

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Abstract

The requirement for sports officials to make accurate decisions in accordance to both the ‘letter’ and the ‘spirit’ of the law is a challenging task. Due to the complexity and ambiguity inherent in sport decision making, error is inevitable. This study investigated the perceptual and cognitive processes that influence decision making accuracy in netball umpires. Umpires from the Netball South community were recruited to complete two decision making tasks, including a theory-based task, and a video-based task. The theory-based task involved questions pertaining to the contact and obstructions laws, which are typical of the theory tests used in the umpire accreditation process. The video-based task required umpires to watch a series of short video scenarios, while wearing an eye-tracking system. The umpires were asked to determine if a penalty was involved or not, as well as providing a rationale, and the cues they used to make that decision. From the video-based task, information about the umpires’ gaze behaviours and decision rationales were identified and analysed to understand how they relate to decision making error. The findings illustrate how different stages along the decision making process can impact decision making error. Umpires who made correct decisions adopted the same visual search behaviour, and looked in the same locations as umpires who made incorrect decisions. However, the higher order cognitive factors, such as interpretation and judgement seem to be the most influential stage in the decision making sequence on the outcome of decision accuracy. Through gaining knowledge and an understanding of how umpires make accurate decisions, it is hoped that the training protocols used in umpire development can incorporate empirically driven research to speed up the progression towards decision making expertise.
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Introduction

The role of the umpire in a sporting competition is paradoxical in nature. While umpires are required to be the omnipotent, all-knowing, all-seeing adjudicator of the laws of the game, they are simultaneously expected to apply a humanistic quality where minor rule violations are forgiven and play is allowed to continue (Colwell, 2000). To expect qualities of humanness is to accept that the expectation of performance perfection is an unrealistic reality. However, the entrenched cynicism of the umpire’s role has been exacerbated by those who do not understand that error is an inherent dynamic in decision making, especially in the complex environment of sporting competition (Mascarenhas, Collins, Mortimer & Morris, 2005). An indirect measure of the quality of an umpire’s performance is in their decision making accuracy, and while error is accepted as a characteristic of decision making in the literature, the real life repercussions for decision making error or poor umpiring performance in competitive sport can have wide reaching effects.

There is increasing pressure for sports officials to become more accountable for their decisions. However, instead of blaming the individual umpire for incorrect decisions, this research proposes that a wider understanding of decision making expertise is developed from an umpire-centred perspective. Through gaining knowledge, we can analyse the current umpire development pathways to determine if they support the cognitive and perceptual needs of the umpire. Therefore, the aim of this research is to develop a deeper understanding of umpiring performance in netball umpires, which can be used to underpin the development of empirically supported and effective training programmes to encourage professional development.

With the professionalisation of sport, the level of excellence required to compete at the highest level is accelerating at an extreme pace. The speed, accuracy, skills and tactical knowledge of athletes are often developed with extensive training using a team of
professionals, such as nutritionists, physiotherapists, team doctors, skills coaches, biomechanics technicians, and mental skills trainers or sports psychologists who are all dedicated to the athlete’s performance enhancement. The sports psychology literature is now beginning to recognise that elite officials require similar development and training as the athletes they officiate (Slack, Maynard, Butt, & Olusoga, 2013). As Slack et al. (2013) identify, there is now growing empirical evidence for the kinds of support that could be effective at encouraging professional development in decision making processes for officials. A significant contribution from this body of research has looked at the differences between experts and novices, which has provided a subset of the literature that is devoted to the factors that determine decision making expertise in sport (Richards, Collins, & Mascarenhas, 2012). Through this research we are able to get a greater understanding of the limitations and expectations on expert decision making, and therefore use this information to design training programmes to enhance decision making ability.

Umpire Decision-Making: The Role of the Umpire

At the most basic level umpires are required to discern the messy, incomplete and dynamic actions of players as being in accordance with, or a violation of, the laws and the spirit of the game (Mascarenhas et al., 2005). Historically, an umpire’s decision held an element of respect where their position of authority was seen as powerful and unequal to all others in the environment. What the umpire saw, created reality, if they didn't see it, it didn't exist (Collins, 2010). There is now assumed parity between the umpires and the other participants in sport, which serves to undermine the umpire’s expert status (Collins, 2010). The availability of improved technology is thought to have played an important role in augmenting referee decision making (Collins, 2010). In many sports such as cricket, rugby league, and tennis an appeal process has been incorporated into the rulebook where captains have the power to
demand a review, which can result in a reversal of the decision (MacMahon, Plessner, Pizzera, Oudejans, Raab (2015). While the declarative or rule-based knowledge for the laws of the game are presumably the same for coaches, players and officiators of sport, they all have different goals in utilising that knowledge (MacMahon, Helsen, Starkes, & Weston, 2007). Coaches learn rules to create tactics and game plans, athletes know the rules to perform within them, and umpires must be able to detect instances where violations of the law have occurred (MacMahon et al., 2007). However, simply knowing the laws of the game in a declarative sense does not determine officiating excellence.

A section of the literature that has attempted to uncover the contributors to officiating excellence across a range of sports has found specific determinants that encompass officiating success. Mascarenhas, Collins & Mortimer (2005) adopted a multi-level approach to develop a model that captured the correlates of successful refereeing performance in Rugby Union officials. Four sources of information were drawn upon to create this model, including a review of the empirical literature, profiling elite referees, reviewing the available umpire training literature, as well as gathering information from referee assessor reports. Five key themes were identified, which included; knowledge and application of the law, contextual judgment, personality and game management, fitness and positioning, as well as the psychological characteristics of excellence (Mascarenhas, et al., 2005). The Rugby Football Union (RFU) had adopted this model to inform protocols for developing English referees, by tailoring umpire training and assessment to each of these 5 key themes.

While each of these themes contribute to the development of an umpire’s decision making expertise, the current review focuses on the paradox that exists between ‘knowledge and application of the law’ with the contextual/game management components of decision making.
The Umpiring Paradox

When a decision is made regarding a potential penalty situation there are two factors that the umpire must consider. Firstly, there are laws and rules that determine the different disciplinary decisions that can be made, such as a ‘contact’ or ‘obstruction’ penalty. However, in situations where an umpire witnesses a minor rule violation, they may make the decision to play advantage if there was no material effect or impact on the non-infringing player (Souchon, Cabagno, Tracelt, Trouilloud & Maio, 2009). This is referred to as a ‘sporting decision’ where flexibility in the application of the law exists to allow for a decision to be made that fits within the context of the game (MacMahon et al., 2015).

For example, the International Netball Rule book (INF, 2015) incorporates the notion of ‘contest’ which acknowledges that physical contact between the players is inevitable. However, if the ‘contact’ is deemed dangerous, against the rules of the game, or disadvantaging one team, then a disciplinary decision is made and a ‘contact’ penalty is awarded. Alternately, if the contact from the offending player didn’t impact or interfere with the non-offending player, then no sanction is awarded. The inclusion of the ‘contest’ specification allows umpires to judge situations based on their own threshold for what they deem an ‘acceptable contest’ in different contexts. In essence, “knowing how to decide accurately is a pre-requisite for deciding adequately” (Schweizer, Plessner, Kahlert & Brand, 2011, p. 431). There is a strict balance between umpiring to the laws of the game, while taking into consideration the ‘art’ of umpiring, because not all decisions that are deemed accurate in accordance to the laws of the game are suitable penalties to give across different contexts (Schweizer et al., 2011).
Decision Making Expertise

Studies looking at expert practice originally used the notion that expertise is developed through at least 10 years or 10,000 hours of practice (Ericsson, Krampe & Tesch-Romer, 1993). With sporting contests typically lasting between 60-90 minutes, an umpire would have to officiate up to 10,000 games (or participate in alternative deliberate practice) in order to be considered an expert. As this is an unrealistic expectation it is now recognised that the quality of the practice is most important in the development of expertise (McMahon et al., 2015). The challenge for novice umpires wanting to develop their skill, is to find environments where meaningful, deliberate practice can take place.

Understanding the factors that contribute to accurate decision making, is thus an important step in identifying the ways a novice umpire can develop their skill in the most effective and efficient way. Research conducted in the sporting domain has looked at the different qualities of decision making by comparing experts and novices, or alternatively those with higher and lower umpiring qualifications or experience (Mann, Williams, Ward & Janelle, 2007).

A consistent finding across the literature is that experts possess superior perceptual and cognitive skills in their domain compared to their less experienced counterparts (Larkin, Berry, Dawson, & Lay, 2011; Mann et al., 2007). As will be covered further on in this review, the basic capacity to search for information in one’s environment does not differ across experience level. Rather, the ability to absorb, process and sort through complex environmental stimuli in a productive and useful manner, is what distinguishes experts from novices (Peitraszewski et al., 2014).

Factors that Influence Umpire Decision Making

Past research looking at the decision making behaviour of sports officials has also focused on the situational factors that impact on the referee’s ability to make accurate decisions.
These factors include; the effect of crowd noise (Unkelbach & Memmert, 2010), umpire stress (Dorsh & Paskevich, 2007), anxiety (Johansen & Haugen, 2013) and the impacts of a team’s aggressive reputation (Jones, Paul, & Erskine, 2002). While this research offers information about the contexts that influence an umpire’s ability to make accurate and non-biased decisions, it does not provide us with an understanding of how umpires make decisions, especially from a perceptual-cognitive perspective (Hancock & Ste-Marie, 2013).

The Perceptual and Cognitive Skills in Umpire Decision-Making

A common challenge for sports officials is in the ability to process partial, misleading and fast paced information under time pressure (MacMahon & Mildenhall, 2012). Perceptual and cognitive skills refer to the ability to locate, recognise and process environmental information in a way that enables prior knowledge to be accessed to help appropriate decisions be made (Broadbent, Causer, Williams, Ford, 2015). It is generally understood that experts do not possess an innate superiority over novices in their perceptual and cognitive abilities, but instead have acquired their proficiency by training these skills in a particular way (Catteeuw, Gilis, Jaspers, Wagemans, & Helsen, 2010). It is thought that those with superior decision making ability have more effective strategies to recognise the visual stimuli presented in their complex environment, categorise those stimuli in a meaningful way, and use that information to make accurate decisions (Schweizer et al., 2011).

Models for Decision Making

There are different models that explain decision making behaviour that are relevant in the umpire decision making literature. Plessner and Haar (2006) suggest a social-cognitive paradigm where decision makers process incoming information in a series of steps involving perception, categorisation, memory processes and integration. This model follows an information processing framework, while also taking into account the way that an umpire interprets social information (Plessner & Haar, 2006). The social-cognitive approach to
decision making focuses on the shortcomings of human information processing and shows how particular biases or errors occur in the decision making process (Wickens, Hollands, Banbury, & Parasuraman, 2013).

Naturalistic decision making models are also important to use in conjunction with the social-cognitive approach, as naturalistic models focus on the strategies that experts adopt in their decision making process in changeable, natural, and fast-paced settings (Wickens et al., 2013). It is assumed that for sporting officials who are operating in fast paced naturalistic settings, information is largely processed in an intuitive manner (Plessner, Schweizer, Brand, & O’Hare, 2009). Intuitive decision making reflects the notion that decision makers who are under time pressures integrate information in a parallel way rather than using analytic or deliberative methods that operate in a serial manner to process information (Schweizer et al., 2011).

Intuitive decision making models such as the recognition primed decision model (RPD) suggest that cues in one’s environment trigger a search in memory for the relevant information to facilitate decision making (Klein, 2003).

Figure 1: The RPD model for decision making.

The RPD model incorporates two processes; pattern matching and mental simulation. Pattern matching is an intuitive process where cues are recognised as being indicative of a particular situation (The outer circle shown in Figure 1). Through experience, decision makers
develop knowledge of which cues are important to monitor in a particular situation. These patterns of cues activate ‘action scripts’, which help determine the correct response in the given situation (Klein, 2003). Expertise, is thus developed through the construction and solidification of recognisable cue patterns and the activation of corresponding action scripts (Klein, 2003).

The reliability of the intuitive pattern matching process is dependent on the more deliberative, and analytical process of mental simulation, which allows decision makers to evaluate and refine their patterns matching skills over time (Klein, 2003). The inner circle shown in Figure 1 highlights this process. This interconnection between intuitive and analytic processes, is essential for the construction and solidification of reliable intuitive reactions to a multitude of potential scenarios. While the majority of decision making occurring during a fast-paced game like netball would be occurring intuitively, analytical style deliberation can occur in post-match analyses or group discussions where the consolidation of these idealised responses is discussed.

The following sections will describe the perceptual and cognitive skills that have been shown to influence expertise and decision making accuracy. The stages identified in the information processing model will be divided into two main categories, which are organised into relevant subcategories. These two categories include; Perception, which looks at visual search behaviour, fixation locations, and the importance of attention. The second category is Interpretation, which focusses on the categorisation of information, memory processes and the overall integration of information involved in the decision making process.

Overview: Perception and Interpretation

In judgement situations the decision maker is faced with a messy environment, rich with information that can be used to execute a decision response (Wickens et al., 2013). In general, the perceptual process is the act of receiving information from one’s environment
through the senses (Peitraszewski et al., 2014). However, perception is not a passive process as decision makers must actively search for and fixate on relevant cues, but also learn to disregard information that has no value for the situation they are judging. This is the process of selective attention which allows the decision maker to pay attention to the cues that they believe are the most important for the decision they are making (Wickens et al., 2013). The cues which are attended to and processed form the basis of the decision makers understanding of the situation, and thus create the foundation of the decision making process (MacMahon et al., 2015). It is vital that the netball umpire creates an accurate representation of the scenario, by perceiving visual cues such as the positions of a player’s arms, body or feet. If the information perceived is accurate, this will lead to faster and more accurate interpretations.

Once the decision maker selects the appropriate cues, the next step in the decision making process is categorisation. The process of categorisation involves encoding and interpreting the perceived information to create a meaningful understanding of the situation (Plessner & Haar, 2006). For example, a netball player’s attempt to defend the ball may be indicative of a penalty situation or not, as the player will either be inside or outside the 3ft marking distance. Therefore, this defending action can be categorised in one of two ways. This categorisation stage is facilitated through memory processes that integrate the umpire’s knowledge of game laws and their prior experiences of similar scenarios. (Klein, 2003).

Finally, all of this information needs to be combined to form a decision (Plessner & Haar, 2006). In an ideal situation, a decision maker would use the information to make a decision in the most analytical and thoroughly thought out way. However, due to the task constraints, the situational context and the time pressures in sport, shortcuts to decision making occur (Plessner & Haar, 2006).
**Decision Making Error**

The stages discussed above explain the different information processing steps that occur throughout the decision making process. From the umpire’s perception of a player’s actions, to the subsequent decision made by the umpire, there are multiple places from where decision making error can originate (MacMahon, et al., 2015). It could be assumed that having a proficient level of perceptual efficiency is a critical first stage in the decision making process, however, higher order cognitive processes such as memory, or interpretation error can contribute to an umpire’s inaccuracy. This review will now highlight how decision making error can arise at each of the different information processing stages.

**Perception**

The ability to detect and process relevant perceptual cues is thought of as the foundation to good decision making (Pietraszewski et al., 2014). Due to the visual system being the main receptor of decision making cues, it is important to understand how an individual’s visual ability influences decision making accuracy. If decision making expertise is distinguishable at the perceptual level, it is believed that certain visual search strategies can lead to more effective information pick-up (Broadbent et al., 2015).

Ghasemi, Momeni Jafarzadehpur, Rezaee, and Taheri (2011) conducted a series of visual tests to look at the differences between groups of referees who were ‘successful’ and ‘unsuccessful’ in a video-based decision making task. An optometrist conducted tests which included tasks to examine accommodation, saccadic eye movements, peripheral vision, recognition speed, and visual memory. The ‘successful’ group out-performed the ‘unsuccessful’ group on all of these visual skill measures.

Ghasemi et al. (2001) suggest that recognition speed and visual memory ability are skills that are obtained through experience and propose that these skills can be practiced and trained to enhance the quality of decision making. The faster an umpire is able to recognise a
movement or action as being indicative of a rule violation, the faster they are able to process their decision, which is an important skill in many fast paced sports. Similarly, visual memory allows umpires to recognise cues as patterns of behaviour they have previously seen. This helps umpires efficiently decide whether the cues they are perceiving match their internalised conceptualisation of a penalty in that context.

These visual skills highlight the importance of recognising and anticipating visual cues. However, this research does not provide any evidence that these simple perceptual skills alone are what determine higher accuracy decision making. It is also important to understand how umpires scan their visual scene to pick up the information they need to make correct decisions.

*Visual Search Strategies*

The visual search strategies that aid in the detection and processing of visual information have been shown to play an important role in decision making processes (Pietraszewski et al., 2014). It is suggested that the accuracy of an individual’s decision can be determined by the way they search for information in their environment (Williams, Davids & Williams, 1999). In a meta-analysis looking at perceptual and cognitive expertise in sport, expert athletes were shown to display fewer fixations, for a longer duration of time compared to novices (Mann et al., 2007). By looking in fewer locations to gather cues, the expert is able to give more attention to the task relevant information that they know, through experience, to be more valuable. In contrast, the visual search patterns of the novice rapidly shift between sources of information, which suppresses their ability to fixate on and gather sufficient information.

Several moderating factors, such as the sport type, the research protocol used, temporal constraints, and the type of testing stimulus used (static slides or videos) influenced the observed differences between expert and novice visual search behaviour (Mann et al., 2007).
When investigating individual studies, rather than a meta-analysis, there is research to suggest that expert and novice umpires do not display differing visual search behaviours.

Abernethy and Russell (1987) looked at both novice and expert badminton players to analyse their visual search patterns using an eye-tracking system. During the experiment participants watched recordings of game footage on a ‘life-sized’ projected screen, and were asked to anticipate where the opposing player would hit the shuttlecock. The results provided evidence to suggest that both the experts and novices were searching their visual field in the same way, a finding that contradicts the meta-analysis conducted by Mann et al. (2007). Abernethy and Russell (1987) showed that the locations that were being fixated on, the order of search behaviour that was being used used, and the time spent looking at each of the fixation locations’, was similar for experts and novices. However, experts had higher decision making accuracy than novices. Abernethy and Russell (1987) concluded that this difference in decision making accuracy was not due to differences in visual search behaviour, rather, it was due to the experts ability to recognise, extract and use relevant information from their visual scene (Abernethy & Russell, 1987).

Abernethy and Russell’s study highlights an important distinction between looking and seeing. *Looking* is measured by the fixation data gathered from eye-tracking systems to provide information about what is being ‘looked at’ (e.g. fixated on). However, from this fixation data, interpretations about what is actually being seen cannot be shown, as *seeing*, refers to the cues that are selectively being interpreted. While the novices were shown to be looking in the same locations, for the same duration of time as the experts, this does not mean they were attending to or using that information to make their decisions (Abernethy & Russell, 1987).

Unlike the simple task in Abernethy and Russell’s (1987) study, the decision making task that umpires face in interactive team sports is much more complex. Umpires are required
to respond to the exchanges between multiple players and therefore, a large portion of information and cues need to be organised and made sense of.

Perceptual Error and Expertise

A key area of research that has been conducted in the umpire based literature has looked at offside decision making in football, where the ‘flash lag effect’ has been hypothesised to be one of the shortcomings of perception (Catteeuw, Helsen, Gilis, Van Roie, & Wagemans, 2009b). This effect suggests that a referee will perceive the attacking player as ahead of where they actually were (offside) at the moment they received the ball, leading to more ‘flag errors’ being made (Catteeuw et al., 2009b). Looking at national and international assistant referees (whose role during the game is to specifically make offside decisions) showed that there were no differences in the visual scan patterns for referees of different expertise, as has been shown with previous research (Abernethy & Russell, 1987). However, it was thought that the international level referees have learnt to ‘deal’ with the flash lag effect and therefore, their decision making accuracy with offside decisions was greater than the national referees. The exact mechanism for this ability was not looked at and the researchers inferred that this skill could be learned, rather than being an innate characteristic of the more expert referees (Catteeuw et al., 2009b).

Only one study was found that combined the research elements of gaze behaviour and decision making accuracy using umpires who make judgements in a dynamic, interactive team sport. Hancock and Ste-Marie (2013) investigated gaze behaviours of 30 ice-hockey referees, which included two levels of experience. The higher-level group had significantly more years of experience in refereeing higher grades of ice-hockey than the lower-level group.

The purpose of this study was to understand the way that eye-gaze behaviour can be used to inform the process of referees’ decision making. The referees were presented with sequences of video clips from previously recorded games that involved a penalty or no penalty
decision. After each video was played the umpires were required to make a decision for what the penalty was. During this procedure, the referee’s eye-gaze behaviour was monitored to obtain fixation behaviour measures including, the number of fixations made on average per video, as well as the duration of these fixations. The umpires’ decisions were sorted into four categories to determine a measure of decision making sensitivity. If the referee correctly identified the penalty, this would be a categorised as a ‘Hit’. A ‘Miss’ denoted a situation where a penalty was present but was not identified, a ‘Correct Rejection’ referred to a situation where no penalty was detected, when there was no penalty present, and finally, ‘False Alarms’ referred to situations where a penalty was detected, when there was no penalty present in the video.

The results suggest that there was no difference between the lower-level and the higher-level referees on the gaze behaviour measures. However, higher-level referees had higher decision making accuracy, as well as better decision making sensitivity. Like the research that has come before it, this study replicates the finding that expert decision makers look for information in the same way as novices. Decision making accuracy is higher for experts because experts are better than novices at extracting the relevant information from the visual scene to make more accurate decisions.

While our visual system provides us with information to make accurate and consistent decisions (Janelle, 2002), it is important to acknowledge that even if one’s perception is an accurate depiction of reality, this does not automatically relate to decision making accuracy (Schweizer et al., 2011). Therefore, the subjective nature of interpretation plays an important role in an umpire’s decision making process.

Interpretation

Once the decision maker detects and processes the relevant perceptual cues, the next step in the decision making process is to interpret the information in a meaningful way. Due to
the complexity and ambiguity involved in fast-paced, dynamic sports, the information umpires receive and can be interpreted in many ways (Souchon et al., 2009). The interpretation stage involves the categorisation of information which is facilitated through memory process, and prior experience.

**Categorisation**

While cue recognition (perception) and utilisation (attention) provide a partial explanation for the differences in ability between referees, it is unlikely that individuals are using singular cues to make decisions. Rather, umpires are likely to categorise an event based off the recognition of a multiple cues. A multiple-cue framework has been proposed, stemming from a Brunswikian perspective that suggests that umpires judge a ‘distal event’ (the occurrence of a penalty) by the proximal visual cues surrounding that event (Schweizer et al., 2011). In this instance proximal variables refer to the cues that can be directly observed.

If the ‘distal event’ is judged on incomplete, or disrupted proximal cues (due to the ambiguity and complexity of a situation) decision making error may occur more readily (Plessner et al., 2009). As a netball example, an umpire may see two players contesting for possession of the ball. One player may gain possession but stumble as they land and lose their balance. In most instances the relevant proximal cue of falling off balance would suggest that this player was pushed by the other, which would justify a contact penalty being awarded. However, a player losing their balance is an ambiguous cue that may have no relation to an incidence of contact (the distal event), as the player who fell off balance may have fallen on their own.

**Intuitive Decision Making and Memory Processes**

Betsch (2008) provides a definition of intuition which highlights the notion of intuitive thinking as a process that relies on the use of past knowledge stored in long-term memory. The attainment and solidification of long term memories that inform intuitive thinking is thought to
be developed through domain specific, associative learning processes with ‘kind learning environments’ (Klein, 2003). These memories are used to create judgement heuristics that develop unconsciously and automatically to guide decision making in uncertain, complex environments (Souchon et al., 2009).

The literature reviewed above demonstrated that expert and novice decision makers are not distinguished by their perceptual skill or gaze behaviours they adopt. However, an umpire’s superior accuracy can be determined by their organisation and understanding of the information that they perceive. This suggests that the information processing stage of categorisation; a higher order cognitive process, could be a distinguishing factor between the success of experts and novices. Dijkstra et al. (2013) identifies two dimensions that contribute to expertise which are related to intuitive decision making; experience, and knowledge.

Experience

An individual’s experience is dependent on the variety of situations that they have encountered in a particular domain (Dijkstra et al., 2013). This experience allows mental models to build up over time to create recognisable patterns of cues that are indicative of particular situations, which form the basis of intuitive expertise (Klein, 2003). In a sporting example, a netball umpire would have witnessed hundreds of penalty offenses in a variety of different contexts, which, overtime helps the umpire develop an understanding of the cues that must be present to constitute a penalty and also, know where to look for these vital cues.

Williams and Davids (1998) provided evidence to suggest that in a video-based anticipatory soccer task, the more experienced players were drawing information or utilising cues from different locations than the less experienced players. The experts spent more time looking at the hip region of opposing players, as well as using their peripheral vision more often to obtain “confirmatory information”. Therefore, through experience, the player knew where to focus their attention to guarantee they would pick up the most critical information to
make the decision. This skill in knowing which locations to focus on, is related to the pattern recognition phase of the RPD model.

*Knowledge*

Knowledge on the other hand refers to the declarative knowledge one has about the domain. Explicit knowledge can be developed through studying the domain. For example, a netball umpire with explicit knowledge would be able to identify the attributes or criteria that must be fulfilled (with reference to game laws) in order to be categorised as a penalty. Therefore, an umpire may intuitively know what the correct decision is (due to experience), but without knowledge, they are unable to verbalise and rationalise why they made that decision (Dijkstra et al., 2013).

The synthesis of experience and knowledge has been shown to be indicative of different levels of expertise. Experts possess both high experience and high knowledge, whereas novices, have not yet developed their intuitive ability. The third category, ‘intermediates’ have have a large bank of experience, however, they may not be able to articulate why they know what they know, or why one situation is indicative of a penalty, and another is not.

The distinction between experience and knowledge for expert and novice referees was noted in a study conducted by MacMahon and Ste-Marie (2002). The aim of the study was to investigate the difference between Rugby Union referees with higher and lower expertise in a penalty recognition task. The participants were required to watch videos and verbally respond with the decision they would make and the sources of information they drew upon to make that decision. It was shown that both levels of referee were likely to correctly identify penalties and ignore non-penalty situations. All referees also used perceptual cues more often than memory cues to make their decisions; however, the expert decision makers used more sources of information overall to rationalise their decisions (MacMahon & Ste-Marie, 2002).
This study highlights the idea that experts have more advanced verbalisation skills, as more sources of information were described in their decision making process than those with lower expertise. Although MacMahon and Ste-Marie, (2002) did not use the term “intermediate” the referees in their sample who had lower expertise may have fallen into this category. Their research provides evidence of cue recognition ability using more intuitive methods, however, it did not detail or specify the exact mechanism that the referees were using. Therefore, it is unknown if pattern recognition is a general skill of expertise, or more domain specific to the particular task.

*Domain Specificity in Decision Making Expertise*

To look at this possibility of domain specificity Catteeuw et al. (2009a) used a football video-based decision making task to look at the game referee and the assistant referees’ decision making ability. In general, the game referee is responsible for making foul decisions and is attuned to looking at contact violations, whereas, assistant referees are primarily looking at violations of the offside law (Catteeuw et al., 2009a). Through investigating the performance of referees on both foul and offside decisions, it was shown that referees performed better at discriminating violations for their game specific role. Assistant referees performed better at distinguishing offside decisions and game referees performed better at foul decisions (Catteeuw et al., 2009a). This may be due to the fact that intuitive decision making abilities develop through domain specific environments (Schweizer et al., 2011), therefore, the referees’ intuitive knowledge was stronger for tasks that they more readily perform, thus highlighting the role of experience in the development of expertise.

*Developing Intuition through Pattern Recognition Skills*

Intuitive knowledge is developed in a domain specific way. In order to develop expertise, effective training tools must be utilised to create opportunities to learn. Schweizer
et al. (2011) created a video-based training tool to enhance a group of referee’s intuitive decision making. The referees were presented with video clips of game sequences. After each video clip the referees were given 5 seconds to indicate whether there was a foul or not. The referee’s responses were given no feedback for whether they made a correct or incorrect decision.

After completing a pre-training measure of their performance on this task, the participants were split into two treatment groups and a control group. The two treatment groups were given access to the training programme to complete seven training sessions, where the first group received immediate feedback on their answer, and the second group received delayed feedback. The control group did not have access to any training between the pre-test and the post-test. The results from the post-test suggest that the football referees in the immediate feedback treatment group significantly improved their decision making accuracy compared to the delayed feedback group and the control group (Schweizer et al., 2011).

It was suggested that this training creates a *kind* learning environment, where a large repertoire of hypotheses can be tested to create a tight coupling between recognising particular cues with the outcome of the situation. By providing the individuals with immediate feedback as well as being exposed to a large library of foul situations, referees learnt the particular cues that are important to look for when making foul decisions. However, it was recognised that this does not necessarily mean that these skills are transferable to real game contexts.

*Video-Based Training to Enhance Umpire Decision Making*

In order to investigate the qualities that encapsulate the cognitive and perceptual factors needed in accurate decision making, a sensitive and reliable measure to tap into the qualities that help to enhance decision making accuracy must be developed (Travassos et al., 2013).
Larkin et al. (2011) suggested that video training could be a good way to distinguish levels of expertise or similarity use it as method to identify talent, create skill-based benchmarks, or as a way to monitor skill progression. Larkin et al. (2014) provide some guidelines to ensure that the video-based tasks that are used are a reliable and valid measures of an individual’s decision making skill. In order to obtain validity attempts must be made to ensure the video content creates the highest level of ecological validity. The use of in-game footage from the umpires’ perspective would be the most preferable method; however, this kind of data is often difficult to obtain due to limitations in technology (Larkin et al., 2014). It is suggested that sideline footage may be more accessible, and therefore is adequate as long as the critical decision making information is observable throughout the video.

**Limitations of the Video Paradigm**

One of the fundamental limitations in decision making research with officiators is that an umpire’s performance will always be determined based on a pre-determined ‘correct’ answer (Rix-Lieve, Boye, & Recope, 2011). Therefore, the focus is on what the decision was, rather than what it could have been, which tends to devalue the umpires’ understanding of contextual awareness. While the laws of the sport determine whether the rules have been broken, there is an interpretative quality to all laws, where the umpires opinion and evaluation of the player’s actions are important.

**Categorisation Error**

The interpretation and categorisation of perceived information has been shown to be influenced by factors outside of the immediate situation (Plessner & Haar, 2006). In accounts of maladaptive cue utilisation, umpires have been shown to be affected by external informational cues, such as crowd noise. A study conducted by Nevill, Balmer and Williams (2002), showed that referees who watched game clips with noise and commentary gave 15.5% more fouls than referees who watched the game clips with no noise. This difference was
attributed to a motivational disposition towards avoiding anxiety and pleasing the home-team’s crowd. Unkelbach and Memmert (2010) extended this paradigm further in a laboratory task, where it was shown that higher crowd noise volumes were associated with more yellow cards awarded, presumably because the louder the crowd noise was, the more severe a foul act was thought to be (Unkelbach & Memmert, 2010).

This research is related to the Brunswikian perspective, where it is suggested that in situations where the umpire has no access to a distal event (the foul situation), proximal cues are utilised to infer what happened. For example, the referee may use crowd reactions (proximal cue) to infer the severity of a potential foul situation (distal event) that they may not have had direct sensory access. While, this may be an adaptive decision making strategy, there is also the increased likelihood that the information they receive biases the categorisation process and influences how information is integrated into a final decision.

Information Integration

Information that is perceived and processed is used to make two type of judgments; including anticipation judgments and decision making judgments (Broadbent et al., 2015). When umpires make anticipation judgments they are anticipating the outcome of a player’s action from the sequence of cues that they are seeing. Decision making judgments refer to the planning and selection of the appropriate response (Broadbent et al., 2015). For both of these decision types, due to the ambiguity of a situation, the judgment must be made on the intent or outcome of an action (Plessner and Haar, 2006). In netball, the umpire is required to determine whether an action caused interference or an unfair disadvantage to the non-infringing player, regardless of whether the infringing action was intentional or not.

Summary

The current study was designed to enhance knowledge around the perceptual and cognitive processes that influence decision making accuracy for umpires in team sports. The
research methodology used both qualitative and quantitative methods to develop an in-depth analysis of decision making for netball umpires. This study seeks to clarify some of the ambiguity of past research, and suggests that for netball umpires, decision making accuracy will not be distinguishable at the perceptual level, rather, decision making error will be explained by differences in the subjective interpretations of the information that is perceived.

The qualitative data that is gathered will provide complimentary information to the quantitative data, and will facilitate the understanding of how netball umpires are consciously attending to information to make their decisions. Through obtaining this information, we can create a better understanding of how netball umpires make decisions, and thus create an empirical base through which to create effective psychological skills training methods to enhance decision making ability and speed up the acquisition of expertise.

Method

Participants

Eleven participants were recruited though the netball community using word of mouth and through already established contacts. An email was sent to a data-base of umpires within the Netball South regional zone. Umpires were required to hold at least a Zone level of accreditation to take part in this study. The umpires were all female, and ranged in age from 17-48, with a mean age of 27.73 years ($SD=13.92$ years) and had been umpiring for between 5-14 years ($M=8$ years, $SD=2.6$ years). Four of the umpires were over 40 years old ($M=46$ years old, $SD=4$), and the remaining seven participants were under 21 years old ($M=18.86$, $SD=1.57$). The umpires had also achieved different levels of accreditation. The International Netball Federation (INF) has a universal qualification system that umpires must progress through to achieve different umpiring qualifications. The most basic accreditation level is the Centre Badge which involves both a theory and a practical component. Umpires can then progress through the ranks by obtaining Zone, NZ C, NZ B, NZ A and finally the IUA, or
international level of accreditation. For the umpires in this current study, two had achieved their Zone Theory qualification; one umpire had achieved the Zone Badge, five umpires had completed their NZ Theory, and three had completed the NZ C accreditation level.

Table 1

Demographics of the Participating Umpires

<table>
<thead>
<tr>
<th>Umpire #</th>
<th>Accreditation Level</th>
<th>Age</th>
<th>Years of Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zone Theory</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>NZ Theory</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Zone Theory</td>
<td>48</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>NZ Theory</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>NZ C</td>
<td>18</td>
<td>5</td>
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<tr>
<td>6</td>
<td>NZ C</td>
<td>48</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>NZ Theory</td>
<td>40</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>NZ Theory</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Zone Theory</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>NZ C</td>
<td>48</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>NZ Theory</td>
<td>18</td>
<td>10</td>
</tr>
</tbody>
</table>

Materials and Tasks for Stage One: Theory Based Decision Making Task

Questionnaire

The umpires completed a brief questionnaire which included questions about their umpiring expertise, their years of experience umpiring netball, their age, and accreditation level.

Theory Test

Throughout the accreditation process umpires sit various theory tests. These tests cover the rules within the International netball rule book (INF, 2015) including questions about the equipment, duration of the game, officials, the team, late arrivals, substitutions, injury/stoppages, and game conduct. For this current experiment, a theory based decision making (TBDM) task was developed. Rather than covering all of the rules covered in the rule book, the TBDM task used in this experiment covered the rules pertaining to game conduct or
what is referred to as ‘major infringements’. Specifically, the obstruction rule, and the contact rule were used.

The structure of the TBDM task followed that of the final section of the Netball New Zealand theory exam. In this format, the scenario is stated, and the umpire is then required to; 1) state what the infringement was 2) state what action would be taken (to penalise or not), and 3) the reason for their decision. For this current experiment, in addition to providing a decision about the infringement and action to be taken, the umpires provided a rationale, as well as an explanation of the cues that they believed were important to make that decision. The participants were also asked to rate the certainty of their decision using a 7-point Likert scale. This was a measure of their confidence, with a 7 denoting that they were 100% certain of their answer, and a 0 conveying high uncertainty in their decision.

*TBDM Task Questions*

The 14 questions that were used in the TBDM task can be found in Appendix A. These questions were written by the primary experimenter, using the International Netball Federation (INF) rule book. The questions and answers were submitted to a Netball South umpire coach; the Subject Matter Expert (SME) to confirm or contest the questions and answers. The SME held her NZ B level of umpiring accreditation so offered an expert opinion superior to any of the umpires in the study. Discussions took place between the primary experimenter and the SME until agreement was reached. Two examples of the questions are provided below.

1) “White GD runs in to defend an attempt at goal. She takes off from the ground at the correct distance and launches herself upward and forward to defend the shot. White GD lands crouched in front of the shooter within 0.9m”

2) “White GD runs forward to receive a pass in the middle of the court. Black GA reads this play and also runs across to the middle of the court. As GD lands (catching the ball), GA lands in front of GD within 0.9m and she raises her arms to defend the ball. GD then steps off
her grounded foot, thus shortening the distance between the two players, positioning them chest to chest. GD finds it difficult to pass the ball”

The first question is a non-penalty scenario due to the White GD being “crouched” in front of the shooter (Rule 11.1 (iv), INF, 2015). The second question is an obstruction scenario, as the GD was within 0.9m with her arms up over the ball, before the attacking player stepped forward. (Rule 11.1 (iii b, INF, 2015)

Example Question Sheet

A sample of the question sheet that the umpires used to answer the questions in the TBDM task is included below.

a) What was the infringement?
...........................................................................................................................

b) What action would you take?
...........................................................................................................................

c) Provide the rationale behind your decision. What cues were important in making this decision? This can be very brief.
...........................................................................................................................
...........................................................................................................................
...........................................................................................................................

d) Level of certainty? (Please circle one)

0 1 2 3 4 5 6 7

Not certain at all 100% certain

Materials and Task for Stage Two: Video Based Decision Making Task

Video Clips and Raw Footage

A video-based decision making task (VBDM) was used in the second stage of the experiment. Participants viewed a series of video scenarios that were recorded from an umpire perspective (the live in-game umpire wore a head mounted camera while umpiring a netball
game). As previous studies have suggested, ecological validity is often sacrificed in decision making research due the footage (recorded from a sideline vantage point) not accurately representing the positioning or angle an umpire would typically make their decisions in (Larkin et al., 2014).

The footage that was obtained was the first of its kind to be recorded using a “ref cam” in New Zealand. The in-game umpire in the footage was one of the top ranked umpires in NZ, therefore, offering the most expert decision making perspective available within New Zealand. The footage was recorded in 2013 during an ANZ netball championship game between the Northern Mystics and the Bay of Plenty Magic.

From the 60 minutes of footage that was available, 25 scenarios were initially picked for the SME to assess. In the assessment of the video scenarios the SME determined if the scenarios offered sufficient clarity for a decision to be made. From the 25 scenarios, 14 were deemed to be of sufficient clarity to be included in the experiment. The “correct” decision was decided upon through comparing the in-game umpire’s real-time decision, with an analysis of the video footage by the primary experimenter using slow motion replay. These “correct” decisions were then confirmed or contested by the SME. If the decision was contested, the final answer was discussed until there was agreement.

Overview of the ASL Mobile Eye-Tracking System

A mobile eye tracking system was used to record eye gaze behaviour during the VBDM task (Mobile Eye, ASL. Bedford, MA). The umpires wore this head-mounted system during the entirety of the task to track eye movement behaviour while they made their decisions. The system involved two cameras (the eye camera, and the scene camera) that interleave their images to create one image. The scene camera records images from the external scene, and provides a broad view of what the umpire is looking at. The eye camera records the movements
of the pupil to create a red fixation location cross hair over the image from the scene camera.

See below in Figure 3, Image B below.

![Image of Mobile-Eye head mounted unit, attached to the RMU and the video recorder.]

*Figure 2.* Mobile-Eye head mounted unit, attached to the RMU and the video recorder.

The video that was gathered from the head-mounted unit was sent to the remote-mounted unit (RMU) which is attached onto a modified digital video cassette recorder (DVCR; Sony GV-D1000E). During testing the DVCR was connected (via a firewire cable) to a laptop computer (Toshiba, Satellite M110) which had Eye-vision software installed on it. The eye-vision software was needed for calibration, so the DVCR was left attached to the Laptop computer throughout experimentation.
Figure 3: Eye-tracker components: Image A shows the position of the scene camera, and the eye camera. Image B, shows the DVCR, and Image C shows the Eye vision software display screen, which is used during calibration to adjust the pupil settings.

Video-Based Decision Making Task

As with the theory test, the participants were required to make decisions about netball scenarios in this decision making task. However, rather than reading the scenarios in a written format, the participants were shown video scenarios which were projected onto a large screen (2m x 1.5m). After each scenario was played, the video was paused and the primary experimenter asked the four experimental questions (i.e. asking what the infringement was, what action should be taken, the rationale/cues that were important to make that decision, and the certainty of the decision). This process was completed for all 14 video scenarios. All of the participants’ rationale’s and cue descriptions were recorded and later transcribed verbatim.

Figure 4. Visual display set-up: Image A shows the experimental set-up with the participants’ view of the video scenarios. Image B is a still frame from the footage that was captured from the eye-tracking system. This footage was used in the coding procedure, where the red cross-hair highlighted the location of the umpire’s fixation.
**Decision Making Variables**

**Decision Making Accuracy:** This was determined by the number of questions that were correctly answered on average across all the umpires in both the TBDM task and the VBDM task. Higher DM accuracy is a measure of more advanced DM skill with regard to the laws and knowledge of netball officiating.

**Decision Making Certainty:** For each decision that the umpires made, they rated their certainty on a Likert scale (0-7). Higher scores indicated a higher certainty or confidence that the decision that they made was correct. Lower scores indicated less certainty or confidence.

**Sensitivity:** It is believed that each umpire has a different inclination towards saying “yes” or “no” to the presence or absence of a penalty in a given scenario. A central theory that is used to predict and explain this response bias is the Signal Detection Theory (SDT; Hancock & Ste-Marie, 2013). The SDT categorises a decision maker’s response in one of four ways; Hit, Miss, Correct Rejection (CR), or False Alarm (FA). If the scenario in question involved a penalty situation (a contact or obstruction occurred) and the umpire correctly identified and penalised this, then the response was categorised as a ‘Hit’. However, if the scenario involved a penalty, and it was incorrectly identified or missed, it was categorised as a ‘Miss’. When the scenario did not involve a penalty situation and this was correctly ignored by the umpire, then the decision was labelled as a ‘Correct Rejection’ (CR). If the scenario did not involve a penalty, but an action was incorrectly penalised, this was categorised as a ‘False Alarm’ (FA) (Hancock & Ste-Marie, 2013)
Past research has used calculations such as d’ prime to determine an umpire’s biases (Hancock & Ste-Marie, 2013). Another method that has been used in human factors research, and will be adopted for the current study, is Predictive Power. Predictive power involves two components, including, positive predictive power and negative predictive power (Szalma, Hancock, Warm, Dember, & Parsons, 2006).

**Predictive Power**

Each decision making scenario requires an umpire to think; “was a penalty involved in the scenario”, which they can respond “yes” or “no” to, resulting in either a correct decision, or an incorrect decision,

Positive predictive power (PPP) refers to the proportion of umpire responses that give a “yes” response, to the number of times their “yes” response is correct. When an umpire’s response is “yes”, this suggests that they believe there was a penalty present in the scenario, and this decision is either going to be a Hit (correct), or a False alarm (incorrect). The PPP formula is: $PPP = \frac{\text{Hits}}{\text{Hits} + \text{False Alarms}}$

Negative predictive power (NPP) is the proportion of “no” responses that an umpire gives, with the number of times their “no” response is correct. Therefore, decisions where an
umpire suggests that there was no penalty in the scenario will either be a CR (correct) or a Miss (incorrect). The formula is: \( NPP = \frac{CR}{CR + Miss} \)

This method suggests a decision maker who is able to correctly identify penalties 100% of the time will have a PPP score of 1.0. However, if they are unable to correctly identify any penalties, this will indicate a PPP score of 0. When a decision maker has an NPP score of 1.0 this would indicate that they are able to correctly reject signals that are not penalties on all occasions, and have no misses. A NPP score of 0 would indicate that umpires are unable to correctly reject any of the signals (Szalma et al, 2006).

**Definitions of Outcome Measures**

**Penalty Type**: The 14 scenarios in the TBDM task and the VBDM task can be categorised as either contact or obstruction penalty types. The contact scenarios involved two players (an attacker and a defender) moving upward or forward to receive, intercept or disrupt a pass. The obstruction scenarios involved an attacking player who was either a) in possession of the ball, with the defending player defending a pass or shot at goal, or b) an attacking player not in possession of the ball, with a defending player defending them. Within these penalty types, the scenario may or may not have involved a penalty.

**Correct or Incorrect Decisions**: Correct decisions were those made by the umpires participating in this study, which aligned with the decision made by the in-game umpire, and then confirmed with the SME and the primary experimenter. Incorrect decisions were decisions made by the umpires who answered differently to the in-game umpire, the SME, and the primary experimenter.

**Visual Search Behaviour Measures**

An analysis of the data gathered from the eye-tracking glasses was conducted to look for differences in visual search behaviour for the 14 VBDM task scenarios. The differences that were looked at included the four visual search behaviour measures, which included; the
mean duration spent fixating; the mean duration spent scanning between fixation locations; the mean number of fixation locations, and the mean duration of each fixation. These measures were converted into percentages of time to control for the different lengths of each scenario. The measures were thus labeled as; the total percentage of time spent fixating, the total percentage of time spent scanning, the number of fixation locations per second and the percentage of time spent in each fixation location.

Definitions for Visual Search Behaviour Measures

A fixation was defined as a situation where the eye stayed stationary for 120 m sec or more; which was three frames (Dicks et al., 2010). The ‘total percentage of time spent fixating’ was the total amount of time during the scenario that the eye-gaze behaviour could be categorised as a fixation. The remaining duration of the scenario was thus eye-gaze behaviour that could not be categorised as a fixation; i.e. the total percentage of time spent scanning. Scanning can be thought of as the rapid eye movements of the umpires looking between different locations (Dicks et al., 2010). The mean number of ‘fixation locations per second’ referred to the number of different locations that were looked at during the scenario per second. Finally, the mean percentage of time spent fixating in each fixation location was calculated using the mean time spent fixating and dividing it by the mean number of fixation locations to determine an average amount of time that was spent looking at each location.

Analysis of Fixation Locations

A total of nine fixation locations were identified and coded for in this study. The fixation locations included; the ball (which was often the attacking player holding the ball), the attacker’s (A) body, arms and feet, the defender’s (D) body, arms, and feet, and the court. The primary event being judged always occurred within the area of interest (AOI). All locations that were fixated upon outside of the AOI were combined and categorised as a separate
location. These locations included the bodies, arms and feet of any players who were not directly involved in the scenario within the AOI, as well as the crowd.

Figure 6: Locations for fixation coding.

Procedure

Stage One: TBDM Task

For stage one of the study the umpires completed the umpire questionnaire and the TBDM task. The umpires were given an information sheet to read through and once happy, they signed the consent form. For the decision making task the umpires were required to provide an answer for each question. Stage one took between 45-60 minutes for the participants to complete.

Stage Two: TBDM Task

For stage two of the study the umpires completed the video-based decision making task. This took place between 4-6 weeks after stage one. Participants were briefed about the requirements of the task, and given the opportunity to ask any questions.

Eye-Tracking System Calibration
The eye-tracking glasses were fitted onto the participant and made secure. A short video was presented to the umpires to familiarise them to the netball footage they would be observing. This footage was not used in the experimental scenarios.

The eye-tracking glasses were then checked to ensure the eye-camera was picking up all movements of the pupil. If the image of the pupil was being lost, then the lens or the glasses were adjusted. Using the instructions on the eye-vision software, the eye-tracking glasses were calibrated. This involved detecting the pupil and adjusting for the right amount of light. A scene calibration was also conducted which required the umpires to fixate on four-six specific locations in their visual scene (Figure 4, Image B shows the black corner markers used for calibration). This process took between 5-15 minutes to complete.

Structure of the VBDM Session

A total of 17 scenarios were selected for this task (three of which were practice clips). The video clips ranged in length from 2.5-6.9seconds. Each scenario began with a black screen labelling the scenario that was about to be shown. This screen played for four seconds, followed by a four second still frame of the scenario that would follow. A red square was overlaid on top of this still image to provide a reference point for the location of the ball (see Figure 7). This red square disappeared after 2seconds. The video clip then played, and was followed by a black screen (the prompt screen), which included the three prompt questions “Infringement, Action Rationale/ Cues”. This was a prompt for both the umpire and the experimenter. The video was paused on this screen and the experimenter asked the participant the prompt questions while recording their answers using a recording device (see Figure 8).
Figure 7: Visual prompts involved in the experimental procedure. Image A shows the labelling screen. Image C shows the still frame that umpires were shown, with the red square indicating the location of the ball. Image B shows the prompt screen that umpires were presented with after viewing the scenario.

The participants viewed the three practice scenarios and verbalised their decisions. Once the three practice scenarios were completed, the participants were informed that the experimental scenarios were starting. They followed the same procedure of watching the scenario and verbalising their answers for all 14 experimental scenarios.

Data Coding

The video footage that was recorded from the eye-tracking system was then used to code each umpire’s fixation locations across the 14 scenarios. All fixation locations were coded manually by analysing the footage frame by frame to see where the red-fixation crosshair was located (see Figure 8, Image A). From the original scenarios that the umpires viewed, which were 2.5-6.9 seconds long, the video files were trimmed in the coding process (1.6-4.42 seconds). This trimming limited the inclusion of irrelevant fixations before and after the penalty event occurred. The video scenarios ranged from 40 frames (1.6 seconds) to 106 frames (4.24 seconds) resulting in approximately 8,000 frames of footage being coded. The output
from the eye-tracking system, included a time-stamp in the top left corner of the image (Figure 9, Image A), which corresponded to a row on the excel spreadsheet that was produced from the ‘eye-vision’ software (Figure 7, Image B).

![Image A: Example of footage with timestamp](image-a.png)

![Image B: Excel spreadsheet section](image-b.png)

Figure 8: Data coding process. Image A provides a sample of the footage gathered from the eye-tracking glasses, with the timestamp in the top left corner. Image B shows a small portion of the excel spreadsheet that was produced.

It is important to note that the coding in this study did not account for changes of fixation within a location. For example, if an umpire was fixating on the middle of the chest of a defending player, and subsequently shifted their fixation to the hip of that player, this would all be coded as the “body”, and therefore, did not show in the data as a fixation change.

Similarly, the fixation data does not account for information gathering that occurred through peripheral vision. Therefore, although the fixation data may not show that an umpire saw a particular cue (the red cross-hair was not focused on that location), they may have picked up the information using peripheral vision. An independent coder then coded 10% of the data. The inter-rater reliability was 94%.
**Missing data**

Data from the eye-tracking system was unavailable for 29 out of the 154 video scenarios (14 videos x 11 participants). There were three umpires who were missing fixation data. One umpire was missing the full set of data due to a failure in the calibration phase of the study. It was hypothesised that the darkness of her iris could not be distinguished against the darkness of her pupil. This umpire still wore the eye-tracking glasses while she watched the video scenarios. For the remaining two umpires, the eye-tracking system was tracking sufficiently during calibration; however, while watching the video scenarios, the software’s ability to pick up eye-movement data fluctuated. For one umpire 57% of her data was lost, and for the other umpire, 71% of her data was lost. In previous studies, the eye-tracking system has been shown to be sensitive to differences in iris colour, pupil size or other factors such as participants wearing heavy eye-make up and sickness (watery eyes).

**Excluded data**

Umpire seven was considered an outlier and excluded from the statistical testing that looked at the relationship between age, years of experience, correctness and certainty due to her having the most years of experience, but the least number of correct answers for the theory tests. One video scenario was excluded from the analyses that looked at the fixation locations in relation to accuracy, due to all 11 participants making an incorrect decision. The umpires were all looking in the wrong location thus the penalty they judged, was not the penalty occurring within the area of interest. However, this scenario will be discussed as a separate case in the discussion section.

**Results**

**Overview**

For the first stage of the analysis the differences between the TBDM task and the VBDM for the measures of accuracy, certainty and predictive power were examined. The
primary parametric tests used for the analysis were paired samples t-tests and correlations. For the second stage of the analysis, the different visual search behaviours and fixation locations were examined for correct and incorrect decisions, penalty and non penalty scenarios, as well as Hit vs FA responses and Miss vs CR responses. Independent samples t-tests were used to conduct this stage of the analysis. Finally, in the third stage of the analysis, a series of scenarios were chosen to examine the umpires verbal responses, which were transcribed verbatim, and used in conjunction to the findings in the visual search data.

Due to the exploratory nature of this analysis, multiple t-tests were conducted to explore a variety of different hypotheses. Using a Bonferroni adjustment calculation, a conservative critical p value of $p=0.01$ ($p<0.0125$) was used instead of $p=0.05$ to reduce the probability of a significant finding due to chance.

**Part One: TBDM Task Vs VBDM Task**

*Decision-Making Accuracy and Certainty*

Fourteen scenarios from both the TBDM task and the VBDM task were analysed to test for differences in accuracy and certainty in decision making.

<table>
<thead>
<tr>
<th></th>
<th>TBDM</th>
<th>VBDM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Accuracy (SD)</strong></td>
<td>11.64 (1.57)</td>
<td>8.73 (1.42)</td>
</tr>
<tr>
<td><strong>Mean Certainty (SD)</strong></td>
<td>6.49 (0.21)</td>
<td>5.53 (0.66)</td>
</tr>
</tbody>
</table>

*Accuracy:* On average across the 14 scenarios in both the TBDM task and the VBDM task, umpires had higher accuracy scores in the TBDM task than in the VBDM task (see Table 2). This difference of 2.91 correct answers, was highly significant $t (10) = 4.77, p=0.001$, with an effect size of $d=1.94$. 
Certainty: On average across all 11 umpires, the ratings of the umpires’ certainty (out of 7) was higher in the TBDM task than in the VBDM task (see Table 2). This difference of 0.96 was significant $t(10) = 6.3, p=0.001$, with an effect size of $d=1.96$, suggesting that as well as being more accurate in the TBDM task, umpires were more certain or confident in their decisions.

Factors that Influence Decision Making Accuracy and Certainty

The next stage of the analysis looked at the factors that influenced the significant differences found for accuracy and certainty across the two tasks. The factors that were believed to have some influence were the umpires’ years of experience, their age, and the accreditation level they had reached.

Table 3

Pearson $r$ Correlations between Accuracy and Certainty Scores for the TBDM and VBDM Tasks with the Umpire Demographic (Correlation Matrix)

<table>
<thead>
<tr>
<th>Demographic</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Years Experience</td>
<td>-0.08</td>
<td>-0.49</td>
<td>-0.06</td>
<td>0.19</td>
<td>-0.12</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>2. Age</td>
<td>-0.08</td>
<td>0.25</td>
<td>-0.04</td>
<td>-0.02</td>
<td>0.49</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>3. Accreditation Level</td>
<td>-0.49</td>
<td>0.25</td>
<td>0.02</td>
<td>0.09</td>
<td>0.43</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>4. Accuracy of TBDM Scenarios</td>
<td>-0.06</td>
<td>-0.04</td>
<td>0.02</td>
<td>0.09</td>
<td>-0.29</td>
<td>-0.28</td>
<td></td>
</tr>
<tr>
<td>5. Accuracy of VBDM Scenarios</td>
<td>0.19</td>
<td>-0.02</td>
<td>0.09</td>
<td>0.09</td>
<td>0.26</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>6. Certainty of TBDM Scenarios</td>
<td>-0.12</td>
<td>0.49</td>
<td>0.43</td>
<td>-0.29</td>
<td>0.26</td>
<td>0.807**</td>
<td></td>
</tr>
<tr>
<td>7. Certainty of VBDM Scenarios</td>
<td>0.06</td>
<td>0.52</td>
<td>0.36</td>
<td>-0.28</td>
<td>0.37</td>
<td>0.807**</td>
<td></td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level

Years of Experience: There was no correlation between the years of experience that an umpire had, with the outcomes of decision making accuracy and certainty. Age: Age had a positive medium correlation with certainty in both the TBDM (.49) and the VBDM (.52) tasks, but no correlation with accuracy. Accreditation Level: The level of accreditation that the
umpires had achieved had medium correlations with certainty in the TBDM (.43) and VBDM (.36) tasks, but no correlation with accuracy. Certainty: There was also a significant correlation (.807**) between the certainty of decision making in the TBDM task and certainty of decision making in the VBDM task, suggesting that umpires were consistent in their certainty across the TBDM and VBDM task trials.

Decision Making Sensitivity and Predictive Power

The proportion of Hits, Misses, FAs and CRs were calculated for both the TBDM and VBDM tasks. The raw scores are presented in Table 4.

Table 4

<table>
<thead>
<tr>
<th></th>
<th>Hit</th>
<th>Miss</th>
<th>FA</th>
<th>CR</th>
<th>PPP</th>
<th>NPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBDM Scenarios</td>
<td>77</td>
<td>11</td>
<td>15</td>
<td>51</td>
<td>0.84</td>
<td>0.85*</td>
</tr>
<tr>
<td>VBDM Scenarios</td>
<td>52</td>
<td>36</td>
<td>22</td>
<td>44</td>
<td>0.72</td>
<td>0.55*</td>
</tr>
</tbody>
</table>

PPP Score: Paired samples t-tests were used to test the differences between the PPP scores for the TBDM task and the VBDM task. The results show that the difference of 0.21 between the PPP score for the TBDM task (M=0.84, SD=0.10) and the PPP score for the VBDM task was (M=0.72, SD= 0.16) approached significance, t (10) =2.2, p=0.052, with an effect size of d=0.89.

NPP Score: Using paired samples t-tests it was shown that the NPP score for the TBDM task (M=0.85, SD=0.15) was larger than the NPP score for the VBDM task (M=0.55, SD=0.09). This difference of 0.30, t (10) =5.9, p=0.001, with an effect size of d= 2.43 was highly significant. A second analysis was run, which excluded scenario 14, as all 11 umpires answered this scenario incorrectly. This was thought to inaccurately represent the Miss responses, and therefore, influence the NPP score. The effect remained significant once scenario 14 was
excluded. The NPP score for the VBDM task was now ($M=0.64$, $SD=0.18$), $t (10) =3.4$, $p=0.003$, with an effect size of $d=1.27$. For all of the remaining analyses scenario 14 was excluded.

These results suggest that umpires have higher negative predictive power in the TBDM task compared to the VBDM task. Therefore, umpires are able to ‘correctly reject’ signals that are not indicative of a penalty more accurately in a theory task compared to a video task. The positive predictive power scores approached significance, suggesting that there is some indication that the TBDM task also allows for easier cue recognition compared to the VBDM task when identifying penalties that do exist. Therefore, the remainder of the analyses looked for explanations behind the increased difficulty in the video-based task.

**Part Two: Visual Search Behaviour and Fixation Locations**

A total of 115 decisions were analysed across the 10 participants whose eye-tracking data were collected for each of the remaining 13 video scenarios. Fifteen decisions or 10.7% of the data were not analysed due to issues with the eye-tracking system.

*Overview for the Organisation for Part Two.*

The visual search behaviour and fixation location analyses were conducted for each of the four stages below. Figure 9 outlines the organisation of these four stages, showing how they relate to one another.

i) Correct Vs. Incorrect decisions (Hit & CR Vs. FA & Miss)

ii) Penalty Vs. Non-Penalty scenarios (Hit & Miss Vs. FA & CR)

iii) PPP Score: Correct “Yes” umpire responses (Hit) Vs. Incorrect “Yes” umpire responses (FA)

iv) NPP Score: Correct “No” umpire responses (CR) Vs. Incorrect “No” umpire responses (Miss)
As Figure 9 suggests, when the umpires believed a penalty was involved in the scenario, they will either be correct (Hit), or incorrect (FA). When they do not believe a penalty was involved in the scenario, they can also be correct (CR) or incorrect (Miss). The first step of the analysis looked at the differences between the correct decisions (Hit & CR) with incorrect decisions (FA & Miss). The second stage of the analysis compared scenarios that involved a penalty (Hit & Miss), with scenarios that did not involve a penalty (FA & CR). The third and fourth stages separated these categories out further to look for differences between correct “yes” responses (Hits), and incorrect “yes” responses (FAs), as well the differences between correct “no” responses (CR), and incorrect “no” responses (Miss).

It is important to note that the comparisons made in stages three (iii) and four (iv), are comparing visual search behaviour and fixation locations from different scenarios. For example, when umpires gave CR responses, these are scenarios that did not involve a penalty.
However, when umpires made Miss responses, these were from scenarios that did involve a penalty. These analyses were included to see if there was an interaction between umpire responses (‘yes’ or ‘no’), if the scenario involved a penalty, and whether the umpire made an incorrect decision.

**i) Correct and Incorrect Decisions**

*Visual Search Behaviour*

The data were first analysed by looking at the differences in visual search behaviour based on correct and incorrect decisions. Of the 115 decisions, 79 decisions were correct, and 36 were incorrect. An independent samples t-test was conducted to examine the impact of visual search behaviour on decision making outcomes. The results suggest that there were no statistically significant differences in visual search behaviour between decisions that were correct and decisions that were incorrect.

**Fixating:** Umpires who made incorrect decisions spent 0.24% less time fixating (\(M=90.93\%, SD=8.6\)) than umpires who made correct decisions (\(M=91.17\%, SD=7.4\)). This difference was non significant \(t\ (113) = -0.15, p=0.88\), with an effect size of \(d=0.02\).

**Scanning:** Umpires who made incorrect decisions spent approximately the same percentage of time scanning between fixation locations (\(M=8.75\%, SD=8.57\)), compared to umpires who made correct decisions (\(M=8.66\%, SD=7.32\)). There was no significant difference between these scores, \(t\ (113) =0.06, p=0.95\), with an effect size of \(d=0.01\).

**Fixation Duration:** Umpires who made incorrect decisions spent an average of 19.99% of the total time of the scenario fixating in each location (\(SD=6.36\)), whereas umpires who made correct decisions spent an average of 21.37% of their time looking in each fixation location (\(SD=7.53\)). This difference was not significant \(t\ (113) = -0.96, p=0.34\), with an effect size of \(d=0.2\).
Number of Fixation Locations: When umpires made incorrect decisions they looked in an average of 4.94 different locations in each scenario (SD=1.43) to gather visual cues, and when they made correct decisions they looked in an average of 4.7 different locations (SD=1.46). This difference was non-significant \( t(113) = 0.85, p = 0.40 \), with an effect size of \( d = 0.16 \). This non-significant finding remained when the length of each scenario was controlled for. Umpires who made incorrect decisions fixated in an average of 2.15 locations (SD=0.78) fixations per second, and umpires who made correct decisions fixated in an average of 2 locations (SD=0.62) per second, with a small effect size of \( d = 0.2 \).

Penalty Type Analysis

These non-significant findings remained when the contact and obstruction scenarios were analysed separately. The full table of results can be found in Appendix B1 (contact scenarios) and Appendix B2 (obstruction scenarios).

The results so far suggest that the basic visual search behaviours that enable umpires to gather information or cues to make a decision, do not differ for decisions that are correct and decisions that are incorrect. Therefore, using the visual search behaviours that were analysed, this sample of umpires all searched for environmental cues in the same way regardless of the decision outcome. However, there may have been differences in where the umpires were looking to gather their cues and the percentage of time they spent looking in those locations.

Analysis of Fixation Locations

An independent samples t-test revealed that umpires who made correct decisions were looking in the same locations, for the same percentage of time as umpires who made incorrect decisions. While small differences did exist between the percentage of time spent looking in each of these locations, the differences were not statistically significant, and therefore, did not influence decision making error. See Table 5 for these non-significant results.
Table 5

Means (% of time) and Standard Deviations for the Fixation Locations across Correct and Incorrect Decisions

<table>
<thead>
<tr>
<th>Fixation Locations</th>
<th>Correct Decisions</th>
<th>Incorrect Decisions</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean % of Time</td>
<td>Of Time</td>
<td>Std Dev</td>
<td>Std Dev</td>
</tr>
<tr>
<td></td>
<td>Viewing</td>
<td>Viewing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball</td>
<td>22.84</td>
<td>22.77</td>
<td>18.72</td>
<td>20.03</td>
</tr>
<tr>
<td>Body A</td>
<td>6.82</td>
<td>8.54</td>
<td>7.63</td>
<td>10.76</td>
</tr>
<tr>
<td>Arms A</td>
<td>0.14</td>
<td>0.86</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feet A</td>
<td>4.28</td>
<td>8.84</td>
<td>5.83</td>
<td>10.1</td>
</tr>
<tr>
<td>Body D</td>
<td>16.39</td>
<td>14.07</td>
<td>17.78</td>
<td>17.27</td>
</tr>
<tr>
<td>Arms D</td>
<td>2.37</td>
<td>5.84</td>
<td>2.97</td>
<td>4.68</td>
</tr>
<tr>
<td>Feet D</td>
<td>4.69</td>
<td>8.84</td>
<td>5.97</td>
<td>10.38</td>
</tr>
<tr>
<td>Court</td>
<td>19.29</td>
<td>15.79</td>
<td>17.92</td>
<td>18.33</td>
</tr>
<tr>
<td>Outside AOI</td>
<td>15.06</td>
<td>13.54</td>
<td>14.13</td>
<td>16.1</td>
</tr>
</tbody>
</table>

Note: ‘A’ refers to the Attacking player, and ‘D’ refers to the Defending player, and ‘Outside AOI’ refers to the percentage of time spent looking outside of the AOI.

Penalty Type Analysis

A separate analysis was run to see if any significance would emerge once the video scenarios were split into their penalty types.

Contact Scenarios: The results continued to show non-significant differences between fixation locations for correct and incorrect decisions. See Appendix B3 for the full table of results.

Obstruction Scenarios: In this analysis the same trend of non-significance was apparent across fixation locations for correct and incorrect decisions. The location of the attacker’s body was trending towards a significant difference, as umpires who made incorrect decisions spent
a higher percentage of time looking at the body of the attacker ($M=6.89\%$, $SD=11.76$) than those who made correct decisions ($M=2.1\%$. $SD=4.69$). This difference of $4.79\%$ was not significant $t$ (33.3) =2.1, $p =0.044$, with an effect size of $d=0.54$. See Appendix (B4) for the full table of the results.

The results thus far suggest that for the umpires in this sample, no matter how the umpire looked (visual fixation behaviour), or where they looked (the time spent in each fixation location) there was no impact on decision making error. Therefore, looking at a particular cue (location) or group of cues, apparently does not influence the umpires’ decision making success. The next stage of the analysis looked at whether the outcome of the scenario; (whether it involved a penalty or not), influenced visual search behaviour and the location of the umpires’ fixations. It was hypothesised that decisions that involve penalties are more complex than non-penalty decisions and therefore, penalty scenarios may demand more cognitive resources, impacting on how and where the umpires look.

### ii) Penalty and Non-Penalty Scenarios

**Visual Search Behaviour**

Of the 115 decisions that were analysed, 64 decisions were made from scenarios that involved a penalty and 51 decisions were made from scenarios that did not involve a penalty.

**Fixating:** Umpires spent $90.78\%$ ($SD=8.56$) of their time fixating on the visual scene in penalty scenarios and $91.49\%$ ($SD=6.46$) of their time fixating in non-penalty scenarios. This difference of $0.62\%$ was non-significant $t$ (113) =-0.49, $p=0.62$, with an effect size of $d=-0.09$.

**Scanning:** There was also a non-significant finding for the percentage of time spent scanning the visual scene, as in penalty scenarios umpires spent an average of $9.22\%$ of their time scanning ($SD=8.56$) compared to in non-penalty scenarios where umpires spent an average
of 8.02% of their time scanning ($SD=6.46$). This difference of 1.20% was non-significant; $t(113)=0.83, p=0.41$, with an effect size of $d=0.16$.

**Fixation Duration:** The percentage of time spent in each fixation location was significantly different between penalty and non-penalty scenarios. In penalty scenarios umpires spent an average of 23.24% of their total time fixating in each location ($SD=7.79$), whereas in non-penalty scenarios umpires spent an average of 18.05% of their time in each fixation location ($SD=5.07$). This difference of 5.19%, was significant $t(113)=4.11, p=0.001$, with an effect size of $d=0.79$.

**Number of Locations:** Umpires looked in 2.34 fixation locations on average per second ($SD=0.67$) in penalty scenarios, and in non-penalty scenarios umpires looked in 1.77 locations on average per second ($SD=0.32$). This difference of 0.57 locations was approaching significance $t(34)=2.43, p=0.02$, with an effect size of $d=1.79$.

**Penalty Type Analysis**

These significant findings were examined further to see if the significant differences remained once the scenarios were split into their penalty types.

**Contact Scenarios:** Umpires spent a higher percentage of time fixating on their visual scene ($M=96.30\%, SD=2.60$) in non-penalty scenarios compared to penalty scenarios ($M=91.81\% SD=5.24$). This difference of 4.49%, was significant $t(28.34)=-3.38, p=0.001$ with an effect size of $d=1.09$. There was also a significant difference between the time spent scanning the visual scene. In non-penalty scenarios umpires spent 3.70% of their time scanning between fixation locations ($SD=2.60$), and in penalty scenarios umpires spent 8.19% of their time scanning ($SD=5.24$). This difference of 4.49% was significant $t(28.34)=3.38, p=0.001$, with an effect size of $d=1.09$. There were no significant differences between penalty and non-penalty scenarios for the percentage of time spent in each fixation location. See Appendix C1 for the full table.
Obstruction Scenarios: The time spent fixating in each fixation location was significantly greater in penalty scenarios (M=24.40%, SD=8.90), than in non penalty scenarios (M=17.75%, SD=5.29), t (57.06) =3.97, p= 0.001, with an effect size of d=0.91. Umpires looked in more locations per second in penalty scenarios (M=2.25 locations, SD=0.72), than in non-penalty scenarios (M=1.73 locations, SD=0.54). The difference of 0.52 locations was significant, t (77) =3.64, p= 0.001 with an effect size of d=0.82. See Appendix C2 for the full table of results.

Analysis of Fixation Locations

The results for the full sample of scenarios have not been reported in this section, but the summary table can be found in Appendix C3.

Penalty Type Analysis

Contact Scenarios: For the contact scenarios 27 out of 36 decisions involved a penalty, and the remaining 9 decisions did not. The significant results have been reported below with the full t-test table available in Appendix C4.

Ball: In scenarios which involved a penalty, the umpires spent less time looking at the ball (M=12.44%, SD=18.32) compared to scenarios that had no penalty involved (M=35.50%, SD=15.95). The difference between these percentages was 23.05% was significant t (15.70) =3.61, p=0.002, with an effect size of d=1.34

Court: In scenarios when there was a penalty involved, the umpires spent a significantly higher percentage of time looking at the court (M=22.74%, SD=17.82) compared to scenarios where there was no penalty (M=3.39%, SD=5.16). This difference, 19.35% was significant t (33.78), p=0.001, with an effect size of d=1.42.
Figure 10: Contact scenarios: Percentage of time spent in each fixation location for penalty and non-penalty scenarios.

**Obstruction Scenarios:** For the obstruction scenarios, 37 decisions out of 79 involved a penalty, and the remaining 42 decisions did not. The significant results are reported below, with the full table available in Appendix C5.

**Ball:** For scenarios which involved a penalty umpires spent a higher percentage of their time looking at the ball; or the attacking player holding the ball, ($M=30.93\%, SD=25.85$), compared to scenarios that did not involve a penalty ($M=17.21\%, SD=17.73$). The difference between these means, 13.72 was significant $t(62.58)$, $p=0.009$, with an effect size of $d=0.29$.

**Court:** For scenarios that did not involve a penalty there was a higher percentage of time spent looking at the court ($M=28.60\%, SD=15.22$) compared to scenarios that did involve a penalty ($M=7.63\%, SD=8.63$). This difference 20.98% was significant $t(66.34)$, $p=0.001$, with an effect size of $d=1.69$.

**Areas Outside of the AOI:** In penalty scenarios there was a higher percentage of time spent looking at the alternative locations in the scenario ($M=19.99\%, SD=17.47$) than when
there was no penalty involved ($M=11.32$, $SD=11.62$). This difference of 2.56 was significant $t(61.35)$, $p=0.013$, with an effect size of $d=0.58$.

Figure 11. Obstruction scenarios: percentage of time spent in each fixation location for penalty and non-penalty scenarios.

**Predictive Power Overview**

The predicative power measures provided information about the diagnostic ability of the umpires. A score of 1 indicated that umpires are able to successfully identify when a penalty was present (Hit), or when a signal was absent (CR) 100% of the time. The Predictive Power measures were calculated separately for contact and obstruction scenarios.

**Contact:** Firstly, the PPP score for the contact scenarios was 0.92, suggesting that when umpires believed a contact was present, they are correct 92% of the time. Therefore, in the contact scenarios for this study, umpires were able to very accurately identify a penalty when it occurred. When umpires did not believe a penalty was present, they had a very low NPP score (0.42), meaning that when umpires thought there was no penalty in a contact scenario, they were only correct 42% of the time.

**Obstruction:** The PPP score for the obstruction scenarios was 0.62, and the NPP score was 0.64. These scores are still relatively low, and suggest that the ability to correctly identify the presence (PPP) or the absence (NPP) of a ‘signal’ was equally difficult in obstruction
scenarios. While the umpires were correct over 60% of the time, there was still a high rate of error in obstruction scenarios.

**iii) Positive Predictive Power: Correct ‘Yes’ Responses (Hits) vs Incorrect ‘Yes’ Responses (False Alarms)**

*Visual Search Behaviour*

For the full sample of video scenarios there were a total of 43 Hit responses and 15 FA responses made. Significant differences were found between Hits and FAs for the percentage of time spent looking in each location, as well as the number of fixation locations per minute. The full table of results are provided in Appendix D1.

*Penalty Type Analysis*

*Contact Scenarios:* For the four contact scenarios there were 22 Hit responses and two FA responses. There were no significant findings for the visual search behaviour between Hit and FA responses. The number of locations that were looked at per minute was approaching significance, as umpires who made Hit decisions looked in more locations ($M=2.25$, $SD=0.67$) than umpires who made FA decisions ($M=1.56$, $SD=0.25$). This difference of 0.69 was non-significant, $t(22) = -1.43$, $p=0.17$. However, it did have a very large effect size of $d=1.36$. See Appendix D2 for the full results table.

*Obstruction Scenarios:* For the 10 obstruction scenarios that were analysed there were 21 Hit responses and 13 FA responses. The percentage of time spent fixating and the time spent scanning were not significantly different between the Hits and FAs. However, the percentage of time spent fixating in each fixation location was greater in Hit decisions ($M=26.18\%$, $SD=9.57$), than in FA decisions ($M=17.98\%$, $SD=5.54$). This difference of 8.2% was significantly different; $t(32) = -2.80$, $p=0.001$, with an effect size of $d=1.05$. The number of locations that were looked at per minute were also higher in Hit decisions ($M=2.08$ locations, $SD=0.62$) than
in FA decisions \((M=1.60, SD=0.43)\). The difference of 0.48 locations was significantly different; \(t(32) = -2.44, p=0.02\), with an effect size of \(d=0.90\). See Appendix D3 for the full results table.

**Fixation Locations**

The results for the full sample of scenarios is not reported in the results section, but can be found in Appendix D4.

**Penalty Type Analysis**

*Contact Scenarios:* There were no significant differences between Hit and FA decisions for the contact scenarios. See Appendix D5 for the full results table, or refer to Figure 12.

![Bar chart showing fixation locations for contact scenarios between FA and Hit decisions.](image)

*Figure 12:* Fixation locations for contact scenarios between FA and Hit decisions.

*Obstruction Scenarios*

*Ball:* Umpires who made Hit responses spent an average of 38.13\% \((SD=26.54)\) of their time looking at the ball (or the attacking player holding the ball), compared to umpires who made FA responses, who spent 18.67\% \((SD=20.59)\) of their time looking at the ball. This difference of 19.46\% was trending towards significance, \(t(32) = -2.25, p=0.031\), with an effect size of \(d=0.82\).
Court: Umpires who made FA responses spent a higher percentage of time looking at the court ($M = 29.49\%, SD = 18.1$) than umpires who made Hit responses ($M = 9.16\%, SD = 10.28$). This difference of 20.33$\%$ was significant $t(16.87) = 3.70, p = 0.002$, with an effect size of $d = 1.38$.

Outside AOI: There was also a significant finding for the percentage of time spent looking in areas outside of the AOI. Umpires who made Hit responses looked in areas outside of the AOI for a higher percentage of time ($M = 18.38\%, SD = 15.09$), compared to umpires who made FA responses ($M = 6.8\%, SD = 7.97$). This difference of 11.57$\%$ was significant $t(31.44) = -2.92, p = 0.006$, with an effect size of $d = 0.96$.

For the remaining locations there were no significant differences between FA and Hit decisions. See Appendix D6 for the full table of results or refer to Figure 13.

![Figure 13: Fixation locations for obstruction scenarios between FA and Hit decisions.](image-url)
iv) **Negative Predictive Power: Correct “No” Responses (Correct Rejections) Vs Incorrect “No” Responses (Misses)**

*Visual Search Behaviour*

For the full sample of scenarios, there were 36 CR responses, and 21 Miss responses. The results for the full sample are not reported in the results section, but are shown in Appendix E1.

*Penalty Type Analysis*

*Contact Scenarios:* For the four contact scenarios there were five Miss responses and seven CR responses given in response to the video scenarios. For Miss decisions, the umpires looked in more fixation locations ($M=2.74$, $SD=0.60$) compared to CR decisions ($M=1.84$, $SD=0.33$). This difference of 0.9 locations was significant $t(10)=3.38, p=0.01$, with an effect size of 1.86.

There was a trend toward significance for the percentage of time spent fixating and the percentage of time scanning the visual scene. Umpires who gave Miss responses spent a lower percentage of time fixating ($M=92.56\%, SD=6.34$) than umpires who gave CR responses ($M=97.02\%, SD=2.19$). However, this difference was not significant; $t(10)=-0.44, p=0.11$, with an effect size of $d=0.94$. As a result of spending a lower percentage of time fixating on the visual scene, umpires who gave Miss responses spent more time scanning ($M=7.44$, $SD=6.34$), compared to umpires who made CR decisions ($M=2.98$, $SD=2.19$). The difference of 4.46 was not significant; $t(10)=1.75, p=0.11$, with an effect size of $d=0.94$. See Appendix E2 for the full results table.

*Obstruction Scenarios*

For the obstruction scenarios there were 16 Miss responses and 29 CR responses made. There were no significant differences between the percentage of time spent fixating, and the percentage of time spent scanning. The percentage of time spent fixating in each location
approached significance as umpires who made Miss responses spent 22.06\% of their time fixating on each location ($SD=7.60$), compared to those who made CR responses, who spent 17.64\% ($SD=5.28$) of their total time looking in each fixation location. This difference of 4.42\% was not significant, $t (23.16) = 2.06, p=0.05$, with an effect size of $d=0.68$.

Umpires also looked in more fixation locations for Miss decisions ($M=2.48, SD=0.80$), compared to CR decisions ($M=1.79, SD=0.59$). This difference of 0.69 locations was significant, $t (43) = 3.30, p=0.001$, with an effect size of $d=0.98$. See Appendix E3 for the full table of results.

**Fixation Locations**

The results for the full sample of scenarios is not reported in the results section, but can be found in Appendix E4.

**Penalty Type Analysis**

**Contact Scenarios**

*Ball:* When umpires correctly rejected a signal as a non-penalisable offence, they looked at the ball for an average of 35.61\% of the total length of the scenario ($SD=18.36$), however, when an umpire missed a penalty they only looked at the ball for an average of 1.97\% of the total length of the scenario ($SD=4.4$). This difference of 33.65\% was significant $t (6.94) = -4.67, p=0.001$ with an effect size of $d=2.52$.

*Court:* Umpires who missed the signal spent an average of 35.09\% ($SD=19.37$) of the length of the clip looking at the court, however, umpires who correctly rejected the signal only looked at the court for 3.77\% of the time ($SD=5.77$). This difference of 31.32\% was significant, $t (10) = 4.10, p=0.001$, with an effect size of $d=2.19$. See Appendix E5 for the insignificant findings not reported here.
Obstruction Scenarios:

**Attackers Body:** Umpires who made Miss responses looked at the attacker’s body for a higher percentage of time ($M=11.92\%$, $SD=13.98$) compared to umpires who made CR responses ($M=2.7\%$, $SD=5.09$). This difference of 9.23 was trending towards significance at the lowered alpha level, $t(17.23) = 2.55$, $p=0.021$, with an effect size of $d=0.94$.

**Court:** Umpires who made CR responses looked at the court for a higher percentage of time ($28.20\%$, $SD=14.08$) compared to umpires who missed the signal ($5.61\%$, $SD=5.5$). This difference of 22.59 was significant, $t(39.34) = -7.65$, $p=0.001$, with an effect size of $d=2.11$. See Appendix E6 for the insignificant results.
Part Three: Verbal Response Analysis with Corresponding Fixation Locations

For the final stage of the analysis nine scenarios were chosen to examine the umpires verbal responses for correct and incorrect decisions. The specific scenarios that were chosen represented the wide range of decision responses that could occur, for both penalty and non-penalty scenarios. Quotations from these responses were used to explain the umpires visual search strategies, the cues they looked for, and why they thought these cues were of importance. It is proposed that in more complex environments such as on the netball court, the basic perceptual processes regarding perceiving and seeing, are entwined with emotional and affective influences that complicate perceptual information gathering, and therefore, influence decision making accuracy (Blanchette & Richards, 2010). The contact and obstruction scenarios were looked at separately for this analysis. Each scenario discussed, will include a fixation screenshot(s) (FS) with corresponding verbal response quotes.

Figure 15: Fixation locations for obstruction scenarios between Miss and CR decisions.
Contact Scenarios: As there were only four contact scenarios in this current study, all four were used for verbal response analysis. These scenarios included three penalty scenarios, and one non-penalty scenario.

Figure 16: Contact Scenarios: Image A, B, and C shows the three penalty contact scenarios, and Image D shows the non-penalty scenario.

Penalty Scenarios

Image A:

AOI: Bodies of the attacking and defending players.

During this scenario, all of the umpires were looking in the AOI at the key moment. In their verbal responses, the umpires all mentioned the main cue, which was the elbow or arm of the defending player pushing out against the attacking player.
Figure 17: Image 1: FS from umpire #2 (Hit). Image 2: FS from umpire #4 (Hit), Image 3: screenshot from original footage.

Hit Decisions (11Hits /11)

All 11 umpires made the correct decision as they identified the action of the defending player as ‘contact’. It is also important that the umpires noted the ‘impact’ or ‘effect’ this contact had on the attacking player. As Figure 18 shows, umpires were fixating on the bodies of the two players in the AOI.

Verbal Responses:

- Umpire #2: “She was pushing her; you could see that she was going off balance”
- Umpire #4: “It looked like contact by the Magic player with her arm as she hit the top of the circle…she got an arm in there to cause her to fall off balance”
**Image B:**

*AOI: Bodies of the attacking and defending players, running to the centre of the court.*

As with the scenario in Image A, all of the umpires were looking in the AOI at the correct moment. However, Figure 19 shows that simply looking in the correct location does not lead to the same decision being made.

![Image 1: FS from umpire #3 (Miss). Image 2: FS from umpire #9 (Hit), Image 3: screenshot from original footage.](image)

**Figure 18:** Image 1: FS from umpire #3 (Miss). Image 2: FS from umpire #9 (Hit), Image 3: screenshot from original footage.

**Hits (9 Hits/11)**

Umpires who made correct decisions saw the defending player come through and knock the ball from the attacking player’s hands. One umpire (umpire #2) was coded as looking at the feet of the two players rather than their bodies; however, in her verbal explanation she referred to the contact incident (which may have been seen using peripheral vision) and a correct decision was made. Therefore, despite being coded as looking in the ‘wrong’ location, this umpire still made a correct response.
"The Mystics player had the ball when she (magic player) hit it out of her hands, when she had control, so…penalty pass" (umpire #2, Hit)

Misses (2 Misses/11)

The remaining two umpires made incorrect decisions. These umpires were both looking in the AOI at the key moment, however, their interpretation of the event differed from one another. Umpire #3’s decision was categorised as a Miss because she called an obstruction penalty rather than a contact penalty. Unlike a traditional Miss where umpires fail to see anything ‘wrong’ with the scenario, umpire #3 made a positive Miss, as she still called the penalty in the correct direction, giving advantage to the player who was affected.

The second umpire who made an incorrect decision interpreted the cues she saw in a different way to the majority of the umpires.

- “I don’t think she actually had possession of the ball, she was kind of waiting for it...so I wouldn’t say there was anything wrong with that” (umpire #8, Miss)

Therefore, despite looking at the same cues in the AOI, and acknowledging that she saw the event, umpire #8 still interpreted the scenario differently.
**Image C:**

AOI: Bodies of the attacking and defending player jumping to catch a high pass.

This scenario was considered the most difficult due to having the highest error rate. To place this scenario in context, the player on the right of the image is the attacking player who was attempting to catch a pass thrown by her team mate (refer to Figure 20, Image 5)

The fixation data for this scenario did not show any specific patterns for where the umpires looked, and whether this influenced their decision making accuracy. For example, some umpires looking in the AOI still made incorrect decisions, and some umpires who were not looking in the AOI made correct decisions.

![Figure 19](image)

*Figure 19:* Image 1: FS from umpire #3 (Hit). Image 2: FS from umpire #1 (Hit), Image 3: FS from umpire #4 (Miss), Image 4: FS umpire #5 (Miss). Image 5: screenshot from original footage

*Hits (5 Hits/11)*

Two of the umpires who made correct decisions were confident in what they saw and how they interpreted the cues. However, as pictured in Figure 20, Image 2, umpire #1 was
fixating her gaze at the feet of the attacker when she should of been looking at the bodies of the two players in order to see the infringement. From the umpire’s verbal response analysis, her verbal explanation suggests she saw the scenario exactly as it played out. Therefore, even though she wasn’t coded as “looking” in the correct location, she was still able to see the penalty occur.

Verbal Responses:

- Umpire #1: “It looked like the Magic defender contacted the shooter in the air, and kind of made her fall backwards as she caught the ball”.
- Umpire #2: “You can see that the GS got up good with two hands, so…and she looks like she strongly got the ball. So it appears like the defender will be pushing her over… “quite a lot of body contact”.

The remaining umpires who made correct decisions, decided to penalise the defending player due to their uncertainty. In Figure 20: Image 1, umpire #3 was fixating in the exact location to see the penalty event occur, however, her verbal response suggests that she still felt uncertain about what she saw. Similarly, umpire #9 had the same uncertainties toward her response, which may highlight a bias toward penalising the defending player in conditions were ambiguity and uncertainty are present.
Misses (6 Misses/11)

The remaining 6 umpires made incorrect decisions. The fixation location analysis showed that in the key moment that the contact occurred, four umpires who said they “couldn’t see”, were coded as looking at either the court or the crowd, thus missing the vital cues to make the decision. This corresponds to the NPP data which suggests that umpires who Miss a contact penalty spend a large proportion of their time (35.09%) looking at the court.

Verbal Responses:

- Umpire #3 “Yea I’m taking a punt on that because I’m not certain”.
- Umpire #9: “I’m not sure who caught the ball, so just giving the attacking team the benefit of the doubt I guess”.

- Umpire #4: “Yea I couldn’t call anything on that because I couldn’t see”.
- Umpire #6: “I couldn’t really see what was happening in the goal circle, if there was any contact, so from what I saw in the clip, I would call....um no infringement”
- Umpire #8: “I could see the attacker, got the ball, and was bumped in the air” “I was kind of looking down, and then I kind of like...I missed it....Umm so I guess let play continue”.
The remaining two umpires who made incorrect decisions reported that they were looking in the AOI and that they saw the potential contact between the two players. However, they interpreted the cues as fair contesting and therefore, let play to continue.

**Verbal Responses:**

- Umpire #5: “Possibly just when they first went up there was a bit of nudging, but nothing that put one player at a disadvantage”.
- Umpire #7: “From what I saw, the players went up, but one came down with the ball, and I thought it was fair contesting”.

**Non-Penalty Scenarios**

**Image D:**

*AOI: The bodies of the attacking and defending player as they move forward to the circle edge.*

All of the umpires were looking in the AOI throughout the scenario; however, differences in the interpretations of the player movements resulted in different decisions,
Correct Rejections (8 CR/11)

The umpires who made CR decisions acknowledged that there was bodily contact between the two players. However, these umpires interpreted that the attacking player wasn’t put at a disadvantage, and therefore, play should be allowed to continue.

Verbal Responses:

- Umpire #2: “I didn’t see anything that happened. She wasn’t too close to her...so I wouldn’t call contact”
- Umpire #10: “Um she was right up the back of the attacker, pushing into the back of the attacker as she was receiving the ball, but I probably would have played advantage on that because she was able to turn and let go of the ball, she wasn’t looking to shoot or anything, she was looking to pass it”.

Figure 20: Image 1: FS from umpire #2 (CR). Image 2: FS from umpire #3 (FA), Image 3: screenshot from original Footage.
False Alarms (3 FA/11)

The remaining three umpires made incorrect decisions. One of the umpires called an obstruction penalty suggesting that the defending player had her arms up defending before she was at a distance of 3ft. This umpire possibly saw the arm of the defender momentarily extend to deflect a pass, but as this was only a very brief movement, it would not be considered an obstruction (INF Rule book, rule 11.2 (i)).

The remaining two umpires believed that a penalisable contact had taken place. They both mentioned that the defender was positioned close behind the attacking player.

Verbal Responses:
- Umpire #3: “She was right up in behind her and there was contact when the GA tried to move once she caught the ball”.
- Umpire #1: “She kind of went into the back of the Magic player, kind of with her forearm in the back”

Obstruction Scenarios: Five of the 10 obstruction scenarios were chosen for verbal response analysis. Three of these scenarios involved penalisable offensives and the remaining two scenarios did not.
Figure 21: Obstruction Scenarios: Image A, B and C showing penalisable obstruction scenarios.

Figure 22: Obstruction Scenarios: Image A, & B showing non-penalty obstruction scenarios

Penalty Scenarios

Image A:

AOI: Grounded feet of the attacker and defender, the defenders arm and distance between the two players.
This scenario had a series of cues within the AOI which needed to be fixated on in order to gather sufficient information to make the decision. The fixation location data suggests that umpires could still make a correct decision without fixating on any of these locations. It is suggested that the positions of the attacking players landed foot, and the timing of the defender’s arm were seen peripherally.

*Figure 23:* Image 1: FS from umpire #5 (Hit). Image 2: FS from umpire #1 (Hit), Image 3: FS from umpire #8 (Miss), Image 4: screenshot from original Footage.

**Hits (6 Hits/11)**

The umpires who made correct decisions interpreted the distance between the two players’ feet or bodies as less than 3ft, but also expressed uncertainty due to the angle and positioning of the video footage from in-game umpire. As Figure 24, Image 1 and 2 highlight, a correct answer could still be given while fixating on the attacker’s body (umpire #1) or by looking at the feet of the two players (umpire #5).

Only two umpires who made correct decisions mentioned the arm of the defender as influencing their decision. These umpires suggested that the hands went up before the defender
got her distance. An analysis of the video suggests that the defenders arm was not up before she was the correct distance away from the attacker. However, because she was too close when her arm went up this is still an obstruction.

Verbal Responses:
- Umpire #1: “Um the player that was defending from behind was well within 3ft…basically how far her feet were away from the shooters grounded foot”
- Umpire #5: Based on where I was standing, she looked short, and she appeared to get her arms up before her distance”

**Misses (5 Misses/11)**

The umpires who made incorrect decisions were looking in the same location as umpires who made correct decisions, however, their interpretation of the distance between the players differed.

Verbal Responses:
- Umpire #8: “The distance seemed ok”.
- Umpire #2: “I think she was far enough away, but the angle was a bit iffy...So I wasn’t too sure how far away she was”.

**Image B:**

AOI: Bodies and feet of the defending and attacking players, the timing the players landing, and arms of the defender.

All umpires were coded as fixating in the AOI at the correct moment. The fixation analysis suggests that umpires spent an average of 50.4% of their time (SD=21.99) looking at the ball (the attacking player holding the ball), and 6.8% of their time (SD=9.5) looking at the attacker’s feet and only 3.19% (SD=7.18) of the time looking at the defender’s body.
Hits (10 hits/11)

This scenario was answered correctly by 10/11 umpires and therefore, was regarded as a relatively uncomplicated scenario. Umpires all looked in the AOI and saw that at the time the attacking player landed, she was already too close to the attacking player, defending with her arms up over the ball.
Verbal Responses:

- Umpire #4: “Her arms were up before she got her distance and she was just too close”.

- Umpire #1: “She wasn’t 3ft when the Mystics player landed sort of next to her, and she put her arms up without moving, so she was kind of well within obstruction range”.

- Umpire #2: “She was within .9 when she was defending. So just looking at her...at how close she was really”. “She was up really big defending as well...so it kind of made it more obvious how close she was to the other person”.

Misses (1Miss/11)

The one umpire who made an incorrect decision started making the decision before she saw the entire scenario. She was fixating on an attacking player (outside of the AOI) who slightly tripped herself up, however, umpire #6 saw this as a contact by another player.

- Umpire #6: “There was an early...sort of contact...by the Magic WA, by the looks of it” “but it didn’t really interfere enough... um yeah I played advantage”.

When she was prompted further about what happened after the perceived contact, she suggested that the attacking player stepped in and therefore the defending player is not at fault for being too close.

- Umpire #6: “I don’t think there was any obstruction or contact...she stepped in I think”.

Although the fixation data suggests she was fixating on the AOI, it is likely that because she was preoccupied with her decision to play advantage on the contact she witnessed earlier, she wasn’t paying attention to the infringement that occurred in the AOI.
**Image C:**

AOI: The bodies of the attacking and defending player within the goal circle.

This scenario was excluded from the analyses because all 11 umpires failed to look in the AOI at the critical time. The umpires were focusing on the location of the ball rather than looking for potential penalties which could be occurring off the ball.

*Figure 25:* The red circle highlights the obstruction that was occurring within the goal circle (the infringement that was missed by all 11 umpires).

*Figure 26:* Image 1: FS from umpire #4, Image 2: original footage.
Misses (11 Misses/11)

All 11 umpires made an incorrect decision in this scenario. While the potential obstruction penalty occurring on the circle edge is not “wrong”, the player was able to continue, thus would only warrant an advantage decision. The obstruction occurring within the goal circle is much more pertinent, because it is more advantageous for the attacking team to have a penalty awarded to them inside the shooting circle, as it maximizes their chances of scoring a goal. None of the umpires scanned into the circle to look for potential incidents off the ball.

Non-Penalty Scenarios

Image A

AOI: The feet of the attacking and defending players, and the body and the arms of the defender.

This scenario had two important phases. These phases included the ‘defending the shot’ phase, and ‘landing’ phase. In the first phase (Figure 28, Image 5) the defender was leaning over to defend the player shooting the ball. In this phase, it was important to acknowledge if the defending player was at the correct distance to defend the shot before she put her arms up over the ball. Therefore, it would be assumed that the feet and arms were important cues to fixate on. The ‘landing’ phase follows after the player had jumped up to defend the shot. In this phase, it was important to acknowledge the position that defender landed in. As the rules state, a player is allowed to be within 3ft after a ‘jump’ to defend the shot, as long as her landing does not interfere with the shooting action of the player (INF, Rule 11.1 (iv))
Correct Rejections (5 CR/11)

As shown in Figure 28: Image 1 and 2, Umpires who made the correct decisions were looking at the court (or the space between the two player’s feet), and therefore, acknowledged that this distance between the two players was sufficient during the ‘defending the shot’ phase.

Verbal Responses:

- Umpire #2: “She was more than 0.9m away...even though she had a good lean. She got her hand down and was out of the way when she landed”.
- Umpire #4: “Based on the fact that her distance appeared fine the whole time, and the shooter had released the ball by the time...like the Magic GD had stood up in front, so there is no obstruction”.
False Alarms (6 FA/11)

Six umpires made incorrect False Alarm responses in this scenario. In Figure 28, Image 4, the fixation location for umpire #1 (who made a FA response) shows that she was looking in the same location as umpire #2 who made a CR response. Therefore, despite looking in the same location, umpire #1 made an incorrect decision.

Verbal Responses:

- Umpire #1: “Her distance was borderline ok to begin with, but when she jumped, I think she kind of landed within 3ft, and I don’t know if her hands were fully down...I think she just sort of interfered”.
- Umpire #9: “On her landing, I’m pretty sure the ball hadn’t been released when she landed”

Image B

AOI: The feet, arms and body of the defending and attacking players.

This scenario was a straightforward obstruction scenario where the defending player was defending an attacking player trying to pass the ball. Therefore, the position of the attacking player’s landed foot, and the defender’s feet at the time her hands went up to defend, was the key moment for this scenario.
Correct Rejections (8 CR/ 11)

Umpires who made the correct decision in this scenario suggested that the distance between the two players was 3ft or more. The fixation analysis suggests that at the key moment, umpires were looking between the feet of the attacker and the defender, as well as the court (as pictured in Figure 29, Image 1)

Verbal Responses:

- Umpire #11: “Um the Mystics defender, the distance was good, timing on putting her hands up was good”.
- Umpire #2: “She landed ok, and the defender was more than .9m away I think, so it would be ok”.

Figure 28: Image 1: FS from umpire #11 (CR), Image 2: FS from umpire #5 (FA), Image 3: screenshot from original footage.
False Alarms (3 FA/11)

Umpires who gave incorrect answers were shown to be looking in the same locations as the umpires who gave correct answers. Umpire #5 (as seen in Figure 269, Image 2) was looking at the space between the feet of the two players. However, the distance between the two players was interpreted as too close.

Verbal Responses:

- Umpire #5: “She shortened her distance, to be within 3ft, while her hands were still up”.
- Umpire #4: “Just looking at the distance between her feet and the ball carrier, just looked a little close”.

Discussion

The aim of the present study was to conduct exploratory research into the perceptual and cognitive processes that influence decision making in netball officiating. To my knowledge, this is the first study that has used a four-stage process with both quantitative and qualitative components to examine umpire decision-making. These four stages included; 1) comparing decision making accuracy and certainty in a theory-based task with accuracy and certainty in a video-based task; 2) visual search behaviour analysis; 3) fixation location analysis; and 4) verbal response analysis. This four step process enabled a comprehensive investigation of decision making processes to take place.

Research that has adopted the expert-novice paradigm consistently shows that experts produce more accurate decisions than novices across a wide range of experimental protocols. The majority of this research has compared expert and novice athletes rather than umpires
Therefore, this current study was developed to examine the variables that may contribute to decision making accuracy for netball umpires.

The inconsistencies in the athlete-centred literature has shown that variability in the sport type or research protocol used, hinders the ability to compare effects across studies (Mann et al., 2007). For the current study, it was important that a differentiation was made between different kinds of sport officiators. For example, Hancock and Ste-Marie (2013) looked at ice-hockey referees due to their decision making role requiring high levels of interaction, and visual cues which are fast moving, ambiguous and complex. These types of official are referred to as ‘interactors’. Unlike those who simply monitor sport situations such as gymnastics judges, ‘interactors’ have far more cues to decipher, and interact more with the players. Therefore, the current study used sports officials who would be also classified as interactors; netball umpires.

Comparing a Theory-Based Task to a Video-Based Task

For the first stage of the study the aim was to examine the way that information is extracted and used when presented in written scenarios compared to when it is presented in video scenarios. As hypothesised, the written theory test was answered more accurately and with more confidence than the video-based scenarios (as seen in Table 2). It is argued that this higher accuracy and certainty was due to the simplified nature of the TBDM task in contrast to the VBDM task. The TBDM task explicitly incorporated all of the necessary cues or information needed to make the correct decision within the written question. Therefore, in the TBDM task umpires were required to read the question and then interpret and judge that information with reference to the rules in order to make a correct decision. This task was completed in the umpires own time, with no specific time pressures. The umpires were able to read the questions multiple times to make sense and interpret them.

However, in the VBDM task (and in real game contexts), the umpire must search for, fixate on, and attend to the relevant cues. This is then followed by an interpretation and
judgment of whether the action significantly interfered with the flow of the game in order to make a correct decision. During this task, the umpires were only permitted to view each scenario once (which was less than five seconds long). Therefore, in order to make the correct decision and give a convincing rationale, the VBDM task placed a large demand on the umpires’ attention, and memory.

Hypothesised Decision Making Sequence

The simplified decision making process for the TBDM task is shown in Figure 29, and the extended, more complex version for the VBDM task is shown in Figure 30.

Figure 29: Hypothesised Decision Making Sequence for the TBDM Task

Figure 30: Hypothesised Decision Making Sequence for the VBDM Task

The disparity shown in accuracy between the theory and video-based tasks highlights that using a theory-based test to examine an umpire’s application of the law for penalty scenarios does not accurately mirror the complex decision making environment that occurs in real game contexts.
Factors that Contribute to Decision Making Error

The remaining analyses were conducted using data collected from the eye-tracking system and the umpires’ verbal responses. From these data results were obtained that provided information about the different sources of decision making error. While each stage of the hypothesised decision making sequence (Figure 30) does not occur in isolation, the following discussion looks at each of the 5 stages separately to understand and explain where decision making error may have occurred along this sequence. This discussion will look at the broad notion of error that was analysed when looking at correct vs. incorrect decisions, as well as understanding the intricacies of error when it was further separated into the stages ii) and iii) in Figure 31.

1) Correct Vs. Incorrect decisions (Hit & CR Vs. FA & Misses)
2) Correct “Yes” umpire responses (Hit) Vs. Incorrect “Yes” umpire responses (FA)
3) Correct “No” umpire responses (CR) Vs. Incorrect “No” umpire responses (Miss)

*Figure 31. Broad and specific notions of error. Comparing correct and incorrect decisions, as well as comparing Hit with FA responses and CR with Miss responses.*

Searching for Cues in the Environment: Visual Search Behaviour

The act of detecting and searching for information in the environment forms the foundation of the perceptual process in decision making (MacMahon et al., 2015). The visual search behaviour that were looked at in this study included; the total percentage of time spent fixating and scanning, the percentage of time spent fixating in each location, as well as the number of locations that were fixated on per second. These visual search characteristics detail how netball umpires look for cues in their environment.

The results provided evidence to suggest that the four elements of visual search behaviour had no impact on whether umpires made correct or incorrect decisions. This suggests that when
looking broadly at the notion of error, *how* an umpire looks, does not determine their decision making accuracy. However, when looking more specifically at error (stages *iii* and *iv*) in Figure 32) there was some indication that elements of visual search behaviour had an impact on error.

For example, when comparing visual search behaviour in obstruction scenarios for FA and Hit responses, umpires who gave FA responses spent *less time* looking in each fixation location compared to umpires gave who gave Hit responses. It was also shown that in both contact and obstruction scenarios umpires whose decisions resulted in a Miss, looked in *more locations* than umpires who made CR responses.

These contradictory results highlight that the success or failure; as defined by correct decisions (Hit & CR) or incorrect decisions (Miss & FA), of different visual search strategies may be dependent on the context they are being used in. Comparing visual search behaviour across different types of scenarios does not allow for the complexities within each scenario to be observed. It is difficult to associate one pattern of visual search behaviour that leads to accurate decision making across all of the unique scenarios.

*Looking: Fixation Location Analysis*

When examining the visual search strategies that umpires adopt, it is also important to determine what cues (locations) are being looked at to inform the umpires’ decision making process. The fixation locations in this study included, the ball (which is often the attacking player holding the ball), the attacker’s body, arms and feet, the defender’s body, arms, and feet, and the court. As with the visual search behaviour analysis, the fixation location analysis looked broadly across error and did not show any significant differences between correct and incorrect decisions. However, when looking more specifically at the error, some locations were associated with more or less decision making accuracy.
In contact scenarios umpires who made Miss responses spent less time fixating on the ball (or the attacking player holding the ball) and more time fixating on the court than umpires who made CR responses. Therefore, ‘Miss’ error is associated with less time looking at the ball and more time looking at the court. It is suggested that by looking at the court in contact scenarios the umpire’s attention is drawn away from the AOI (which is where the contact infringement is occurring). This increases the likelihood that the vital cues needed to make a correct decision are not seen. However, when fixating on the location of the ball (or the attacking player holding the ball), the decision maker’s focus will be within the AOI, which allows them to see the potential infringement take place.

For obstruction scenarios the fixation location of the court provided mixed results on the impact of decision making accuracy. Umpires who made FA responses (error) spent more time looking at the court than umpires who made Hit responses. However, umpires who made Miss responses (error) spent less time looking at the court compared to umpires who made CR responses. This shows that the two types of error (FA & Miss) occurred regardless of whether more or less time was spent looking at the court. This may be due to the subjective nature of the obstruction rule. While 0.9m or 3ft is an objective, measureable distance, each umpire will have their own internal measurement for how they judge this distance. Therefore, unlike contact scenarios, where it seems vital that umpires refrain from looking at the court (in the likelihood that they will miss the event occurring in the AOI), in obstruction scenarios, looking at the court is neither indicative of error or successful decision making.
The ‘Court’ as a Decision Making Strategy for Obstruction Decisions.

*Figure 3*2: Obstruction scenario showing ‘court’ fixation locations. Image 1: A fixation coded as the court, where the umpire is looking at the distance between the bodies of the two players, Image 2: A fixation coded as the court, where the umpire is looking at the distance between the feet of the two players, Image 3: Screenshot from the original footage.

When the location of an umpire’s fixation was coded as the ‘court’, it is argued that the umpire is actually fixing their gaze between the feet or bodies of the two players in the AOI as shown in Figure 32. By fixating on the space between the two players, umpires are able to gather valuable information from both sources of information using peripheral vision, without having to switch their gaze between the two locations. It is important to note that as explained above, the strategy to position one’s gaze in the middle of two players (looking at the ‘court’) does not necessarily indicate decision making accuracy. This visual search strategy has been termed ‘anchoring’ or ‘pivoting’ (Williams, 2000).

*Attentional Strategies*

The ability to divide attention between multiple sources of information is an essential skill for umpires. With the potential for over 100 penalisable offenses occurring in a netball
game (, umpires must be vigilant and maintain attention to pick-up relevant information. This requires umpires to adopt attentional strategies to ensure that vital information is not missed. For example, in order to categorise the obstruction scenario shown in Figure 33 as a penalty scenario, or a non penalty scenario, the umpire needs to obtain two pieces of information. Firstly; are the two players 0.9m away from each other? and secondly; was the defender attempting to defend (arms up) at any time when she was closer than 0.9m? The ability to attend simultaneously to multiple cues such as the feet, bodies and arms of the two players, relies on attentional strategies to prioritise and select the most relevant cues.

Hutterman, Memmert, Simons, & Bock (2013) categorised two attentional strategies including the ‘fixate centre’ and the ‘fixate target’ strategy. The fixate ‘centre’ strategy occurs when the fixation is located in the middle of two stimuli (as seen in Figure 33), and the ‘target’ strategy is when the decision maker fixates on one of the stimuli, while processing the second peripherally. In the research conducted by Hutterman et al. (2013) expert and novice athletes completed a simplified attention allocation task with two experimental conditions (fixate centre and fixate target). In the two tasks both of the attention demanding stimuli used were of equal importance to make a correct response, and therefore, equally demanding of attention. The results showed that the ‘fixate centre’ strategy led to more accurate decision making, as both stimuli could be processed with equal attention. However, with the ‘fixate target’ strategy the first stimulus was given priority, degrading the processing on the second stimulus. The researchers noted that if one stimulus required greater effort and demanded more attentional resources, then it may be more beneficial to fixate on the critical cue and adopt the ‘fixate target’ strategy (Hutterman et al., 2013).

As an example from the current study, a failure in attentional allocation became apparent in the scenario where all 11 umpires made an incorrect decision. The eye-tracking data that was obtained from 10 of the umpires was consistent with the assumption that the
umpires were all looking in the wrong location. The fixation location analysis provided evidence to suggest the umpires were watching the ball, and therefore, missed the obstruction that was occurring off the ball (in the goal circle).

*Figure 33: Missed obstruction penalty: The red circle highlights the critical obstruction that was occurring ‘off the ball’.*

Unlike the umpires who took part in the study, the in-game umpire had the foresight to shift his attention away from the ball to see if any penalisable offenses were occurring in the goal circle. His experience may have assisted him to recognise previously observed patterns, and thus intuitively know that an offense could be occurring in the goal circle. In a scenario such as this, the in-game umpire would intuitively know which attentional strategy would be the most efficient for picking up all of the necessary information needed to make a decision. For example, the in-game umpire may have been fixating in the centre of the two stimuli (the player with the ball on the circle edge, as well as the players within the goal circle). Using peripheral vision, the umpire was then able to decide, that the offense occurring inside the goal circle was more urgent, thus allocating his attention to this location.

It seems that this ability to know when to adopt a particular attentional strategy is closely linked to the concept of expertise and intuitive knowledge. Through experience, umpires develop mental models from recognisable patterns of cues (Dijkstra et al., 2013). Over time they learn what cues must be present to constitute a certain kind of penalty and therefore, the cues that can facilitate the anticipation of players actions. The ability to know when to adopt
particular attentional strategies is an area where further research is needed, and is a skill that is important for novice umpires to acquire.

*Seeing: Attending*

While the fixation location analysis is an important step in understanding the cues that umpires fixate on to make their decisions, these data alone are not sufficient in detailing the complexity of the decision making process. The data gathered from the fixation location analysis highlighted the simplistic aspect of *looking*, which refers to the process of detecting cues in the environment. However, the fixation location analysis was unable to tap into the process of *seeing*, which is related to the concept of selective attention where important cues are attended to, and irrelevant cues are ignored (MacMahon et al., 2015). Therefore, the crux of the *looking* Vs. *seeing* dichotomy is that the location of an umpire’s fixation does not automatically specify what is being attended to.

To strengthen the credibility of the fixation location data the verbal response analyses were used to provide an insight into the umpires thought processes and what they were attending to or *seeing*. These verbal responses were either consistent with, or inconsistent with the fixation location data. When the two sources of information were consistent, it meant that the fixation location data matched the umpires verbal response. For umpire #2, in Figure 17, Image 1, her fixation data showed her looking at the bodies of the two players. Her verbal response was consistent with this as she said described the contact that occurred between them. However, when the two sources of information were inconsistent, it meant that the locations that were identified in the fixation data, were not mentioned in their verbal response. The fixation data for umpire #1, in Figure 19, Image 2, suggested that she was fixating in the AOI, however, in her verbal response she said she couldn’t make a decision, because she couldn’t see. Therefore, while she was “looking” in the correct location, she was not attending to or *seeing* what she was fixating on. Further, if the fixation data showed that the umpire wasn’t
looking in the AOI, but her verbal response described the situation exactly as it happened, it is argued that peripheral vision may have been used to *see* the cues.

*Seeing with Peripheral Vision*

The inconsistencies between what is being fixated on, and what is being attended to, does not impact directly on decision making accuracy due to information gathering that occurs using peripheral vision. One of the fundamental limitations of this research is the inability to separate information pick-up that occurs through central or peripheral vision. The information that the eye-tracking system produces cannot distinguish whether attention is being allocated in the location of the line-of-gaze, or whether the line-of-gaze is “simply a convenient anchor point from which to extract information from the visual periphery” (Ryu, Abernethy, Mann, Poolton, & Gorman, 2013, p. 592). Therefore, the potentially vital role of peripheral vision in expert decision making is difficult to determine in this study.

*Interpretation of the Cues*

Due to the inherent ambiguity in many sporting decisions, a scenario can be interpreted in many different ways. In the current study, there were cases where umpires who made incorrect decisions searched for cues in the same way as umpires who made correct decisions; they looked in the same locations, and attended to the same information, but errors were still made. This can be categorised as an interpretation error, where the umpires’ judgement about a passage of play differed based on their subjective understanding of the scenario. Where one umpire may see a ‘slight’ push as contact, another umpire may see this as fair contesting. Therefore, there is an inherent subjectivity within decision making judgments in netball.

The subjective nature of decision making is highlighted in the language used in the rule book. The obstruction rules include words such as ‘effort’ and ‘interference’ to determine whether a penalty should be given. For example, if there is no *effort* made to defend, or if there
is no *interference*, then a player can be within 0.9m (INF, 2015). This subjectivity is also written into the contact rules, where words such as ‘accidentally’, ‘deliberately’, and ‘interference’ are used. Without clarity around what constitutes an ‘accidental’ or a ‘deliberate’ interference umpires must develop their own standard or threshold for how they interpret every potential offense. This interpretive quality leaves opportunity for error due to individual threshold differences.

During the development of this study, the 2015 version of the INF rule book was released. Unlike the earlier version, the 2015 release specifically included a section defining ‘interference’ (Rule 12.2; INF, 2015). This is a step towards clarification and standardisation of often diverse applications of the law. The clarification of definitions is also a part of post game briefings and review sessions. This regulation is a necessary process to develop more consistent umpiring across all levels of competition.

*Verbal Response Deliberation and the Disruption of Intuitive Decision Making*

The verbal response analysis provided a helpful insight into what the umpires were attending to, as well as how they rationalised and made sense of the cues they saw. However, this opportunity to verbalise their decision making process, may have influenced their final decision. The current study did not include any specific time pressure on the umpires, which gave them extra time to deliberate and rationalise their decision before verbalising it. However, this extra time to deliberate may not have improved decision making accuracy for all umpires.

Dijkstra et al. (2013) suggest an important differentiation for levels of expertise across the domains of experience and knowledge. ‘Intermediate’ decision makers have mastered the execution of their skill and thus have high experience (intuition), but lack the knowledge to explain or give a rationale behind their decision in the way that experts can (Dijkstra et al., 2013). It is argued that if ‘intermediates’ are asked to deliberate the reasons behind their decision, they will not be able to do so due to their limited knowledge. Experts’ superior
performance on decision making tasks relies on automatic processes that have been developed through domain specific learning (Zoudji, Thon, & Debu, 2010).

The research from this current experiment showed that in some cases umpires who gave the correct answer, had poor verbal reasoning skills to explain their decision.

- Umpire #8: “At a stretch she possibly could be obstructing, but I couldn’t see from the camera angle whether there was an inside arm going, so I’d…um…let play continue. “So I was looking at her um arms…. well the outside arm was fine, but oh actually can I change my mind? I’m going to say she obstructed… not the outside arm, the inside arm possibly holding her…as kind of like a bar…Oh maybe that’s contact? I’m really confusing myself. So I’ll lock in obstruction”.

The umpires’ initial intuitive decision (although tentative) was that the she would award an obstruction penalty. As she continued to explain why she made that decision (increased deliberation), she started to change her mind and become flustered and confused. In the end she made the correct decision, however, the opportunity to deliberate interrupted her initial intuitive decision.

One of the hypotheses, for this greater cost of deliberation for novices is the knowledge-based theory (Zoudji et al., 2010). This theory specifies that that reliability of an experts’ intuition increases with experience, and therefore, practice within the domain enhances both domain specific knowledge, and the efficiency of the encoding, storage and retrieval of this knowledge (Zoudji et al., 2010). It is suggested that expert umpires can use part of the long term memory (long term working memory, LTWM), in the information processing and retrieval process, which speeds up the decision making process. The activation of this retrieval structure (LTWM) is important for decisions that need to be made in fast-paced sports like
netball, as information can be retrieval in an automatic, implicit way, which does not disrupt processing within the working memory (Zoudji et al., 2010). Unlike experts, novices have not developed this LTWM and therefore, the attempts to retrieve declarative knowledge to rationale a decision, disrupts the working memory, causing interference in the intuitive knowledge the ‘intermediate’ umpire has.

Making a Decision

The final step in the hypothesised decision making sequence involves penalising an offense, calling advantage or allowing play to continue. If the main source of error didn’t arise at the perceptual or interpretative stage, then a variety of alternative decision making factors can contribute to error. These factors include; umpiring style and biases, the wider game context, and the level of competition. Despite netball’s reputation as being ‘whistle-driven’ with excessive amounts of umpire involvement, the themes discussed below all relate back to the concept of ‘game management’ whereby decision making skills are utilised to create game flow.

Game Management

Game management skills are an essential component in the development of umpiring excellence. The most pertinent component of game management for decision making is contextual judgement (MacMahon et al., 2015). Contextual judgement refers to the notion that not all decisions that are deemed accurate in accordance with the letter of the law, are the best decisions in every context. Within this definition, the concept of ‘material effect’ is important as it suggests that umpires should refrain from penalising an offense, when doing so would put the non-offending team at a disadvantage or if there was no ‘material effect’ on the game.

The advantage rule is commonly applied in sporting decisions where this concept of material effect is considered. In netball, the use of the advantage rule is usually adopted as a communication tool so the umpire can verbalise and acknowledge that they witnessed a penalty
occur. However, because the team who was penalised against was able to continue despite the violation, there is no need to blow the whistle and the advantage is effectively ‘over’. In sports such as rugby union, the use of the advantage rule is slightly different as it can last multiple phases of play. This gives the team who was penalised against the opportunity to recover and play on. If they are unable to gain a significant advantage, the referee will blow the whistle and enforce the original penalty.

This element of game management may have influenced some of the decision making processes of the umpires in the current study. In the current study, the video scenarios were edited to end as soon as the potential infringement had occurred. Therefore, in some scenarios, the judgement of material effect could not be accurately measured because it was often difficult to see the outcome of a contact or obstruction.

_Umpiring Style and Biases_

The ability to make decisions based on the context of the game is related to an umpires internalised style or bias. MacMahon et al. (2015) highlighted two styles of referee; the ‘contest umpire’ and the ‘momentum umpire’. The contest umpire will judge each situation as a distinct event, and see both players as rightful contestants for the possession of the ball. The contest umpire will make a judgement based on one player’s ability to exert dominance over the other. On the other hand, a momentum umpire will typically give the benefit of the doubt to the attacking team, and may have a higher threshold for acceptable behaviour to allow for game flow.

It is suggested that a momentum umpire may have a bias toward making Miss or CR decisions. Rather than making a penalty decision (which may disrupt the flow of the game), they allow play to continue. By saying “no penalty” the momentum umpire either be correct (CR) or incorrect (Miss). In the results from the current study, the low NPP score (0.42) for contact scenarios indicates that umpires may have been adopting a momentum approach to
their decision making. This decision to let the game flow by saying “no penalty” resulted in a high proportion of Miss responses.

As suggested above, the structure and editing of the video scenarios, may have taken away the umpires’ ability to judge material effect accurately, therefore, leaving the umpires to infer what they think happened after the video was stopped. This may have contributed to the high proportion of Miss responses. It can be argued that the decision making environment in the video-based scenarios did not accurately re-create a typical game, and skills learnt using this type of protocol may not transfer into real life contexts.

**Decision Making Context**

While the current study utilised good quality, umpire-perspective footage, other potentially important contextual factors weren’t incorporated. For example, past research has shown that factors such as crowd noise, umpire stress and anxiety, as well as the aggressive reputation of the team can influence an umpire’s likelihood of making correct decisions (Unkelbach & Memmert, 2010., Dorsh & Paskevich, 2007., Johansen & Haugen, 2013). The scenarios in this study were played with no sound to avoid any influence from the in-game umpire. While this was a necessary omission, the removal of crowd noise may have removed some of the ‘real-game’ pressures of umpiring.

Various other contextual factors such as the score of the game, previous penalties awarded, how much time was remaining in the game, the level of importance of the game, and previous rivalries between the two teams, were unknown (McRobert, Ward, Eccles, & Williams, 2011). Throughout a game these factors may contribute to a shift in an umpire’s pre-established threshold toward penalising an action. For example, Plessner and Betsch (2001) showed that for penalty decisions in football, the umpires’ previous decisions influenced their subsequent decisions. If no prior penalty had been awarded, this increased the probability of the umpire awarding a penalty in the second scenario.
In a netball example, if a player committed a minor violation at the start of the game, the umpire would have played advantage and allowed play to continue. However, if the player continuously committed this violation in the last five minutes of the game, when the score was very close, the umpire may begin penalising this ‘minor’ violation. This suggests that if more contextual factors were included in the current study, different rationales which may have incorporated aspects game management, could have been used, leading to different decisions.

**Level of Experience**

As well as the various contextual factors that influence decision making in sport, Souchon et al. (2009) propose that the standard of competition can influence how the same transgression is judged. Novices beginning to play sport have a less advanced set of skills than experts. Therefore, when umpiring youth players, the threshold for what is deemed a penalisable offense (e.g. a contact) would be lower than the threshold for older, more experienced players. It is expected that expert players will be less affected by ‘rough’ play, whereas there is an issue of safety for young children, so rough play isn’t tolerated. For other violations of the law such as; a short pass, stepping, offside, or replayed ball, the threshold for what is deemed acceptable will be higher for novice players, as they will be ‘let away with’ more than more experienced players due to their relative lack of skill.

Souchon et al. (2009) examined referee decisions during handball matches at regional and national levels. The results showed that umpires made different decisions based on the level of competition. For example, umpires intervened less at the national level and were also more lenient for obvious transgressions. The researchers noted that future research should seek to understand how the expertise of the referee across different levels of competition could influence their decision making (Souchon et al., 2009).

The umpires in the current study had no experience umpiring the level of competition that was used in the video scenarios. This inexperience may have altered their natural biases
toward making specific decisions. The umpire’s internalised, pre-established ‘rules’ for what they deem a penalty offense had to accommodate this higher level of performance, which may have led to more error. For example, in the current study the NPP score for contact scenarios was fairly low (0.42), as umpires incorrectly let play continue despite an offence occurring. This suggests that the umpires ‘gauge’ for what constituted ‘contestable’ or ‘fair’ contact was calibrated incorrectly for this level of competition. It is likely that this higher standard of competition created more complexity and thus more ambiguity, forcing umpires to rely on decision making heuristics that they had not adjusted or calibrated for the higher standard of competition.

It is important to understand that the reliability of one’s intuition increases with experience. If the decision maker has experience at an advanced level, they are more likely to have built the mental models to make decisions in more complex situations. However, mere experience does not ensure expertise. If an umpire is not exposed to challenging and ambiguous scenarios during the development of their experience, they will not have learnt how to respond to these more challenging situations when they do encounter them in a real game context. Rather than relying on experience to develop this intuitive skill, training can be developed to expose umpires to more complex and ambiguous scenarios, so that when they do progress to higher grades of officiating, they have already begun developing the mental models for how to respond.

**Overall Sources of Error**

The ability to quickly recognise, make sense of, and process visual cues is acknowledged as a crucial factor in expert decision making. However, the perceptual and cognitive factors that influence decision making accuracy for experts and novices remain unclear (Ryu, et al., 2013; Mann et al., 2007). The visual search patterns that underpin the extraction of meaningful information are very context specific, and therefore comparing across
different sports, or research paradigms can mask the potential subtitles that exist. Even within a game such as netball, the ‘ideal’ visual search behaviour is likely to be different for contact, and obstruction penalties. There may also be different ‘ideal’ patterns of looking based on the position of the players on the court.

When investigating the global concept of error (correct Vs incorrect decisions), the current study supports research conducted by Abernethy and Russell (1987), and Hancock and Ste-Marie (2013), which shows that visual search behaviour is not different for experts and novices (or as the current study showed, those who make correct and incorrect decisions). Rather, decision making accuracy is influenced by the ability to extract and make sense of the information which is attended to.

From the data collected in this study, decision making error is largely attributable to the subjectivity of the interpretations of the scenarios. Even within the theory based decision making task, where there was no need to ‘search for’, or ‘fixate on’ cues, the interpretation of information determined decision making accuracy. The interpretation skills that an umpire has, relates to the knowledge component of expertise. The ability to relate intuitive decisions to a source of knowledge that can justify their decision making reasoning, indicates decision making expertise. Therefore, it is suggested that the ‘knowledge’ component of expertise should be developed further, so that researchers can understand how experts make their decisions, and thus facilitate the construction of more informed, empirically supported programmes for umpire development and training.

_Umpire Development in Netball_

The increasing skill level, athleticism and tactical knowledge of netball players has amplified the physical contest in competition and thus has increased the demand on umpires to advance their officiating expertise. At the ‘centre’ level of the accreditation system, netball
umpires are required to pass both a theory and practical component in order to receive their accreditation. The inclusion of both theoretical and practical components is important, however, the question needs to be asked whether all of the available resources are being used to effectively and efficiently enhance umpire performance.

Current accreditation programmes in netball and sport in general, lack the kind of training that supports learning beyond that of the law-based, declarative knowledge retrieval (Schweizer et al., 2011). It is important to develop new and innovative ways to enhance the quality and accuracy of an umpires decision making skills without having to rely on experience gained in real game settings (Schweizer et al., 2011). Video-based training is a good strategy to use as it holds exactly the same information for every participant, which allows researchers to make comparisons about the way the information is used and how this relates to the accuracy of that decision (Mascarenhas, Collins, & Mortimer, 2002).

**Verbal Response Research**

To comprehend the complete decision making process, additional ecologically valid information must be obtained. Elite umpires who have developed expertise offer a unique subject through which to gather this information. The current study attempted to investigate the cognitive processes behind accurate decision making through the inclusion of the verbal response component to the study. However, more formalised, structured interviews could be used to gain a deeper understanding of expert decision making.

Hancock and Ste-Marie (2014) adopted an insightful verbal response protocol where elite and novice ice hockey umpires wore helmet-mounted cameras while umpiring a game. This footage was then used for simulated recall interviews after the match. While viewing the footage the umpires were asked what cues they were attending to, why they attended to those cues, and how those cues affected their decision making. In the interviews three main decision
making strategies were found; including primary and secondary strategies, as well as cognitive/situational strategies. The primary strategies included; the maintenance of a broad attentional focus, watching the puck carriers, and watching for potential infringements. Secondary strategies involved actions that were used to monitor the players outside of the umpire’s immediate focus, which were subcategorised as; scanning, peripheral vision and watching away from the puck carrier. Lastly, the cognitive and situational strategies were factors that either directly or indirectly influenced the primary and secondary strategies. These included; game context, positioning, anticipating, and prioritising situations.

The expert umpires showed more sophisticated decision making strategies by verbalising their use of secondary and cognitive/situational strategies more often than novice umpires. For example, in regard to prioritising situations, only experts (and not intermediate or novice umpires) verbalised the process of extracting and prioritising which information is the most important, based on the probability of an action occurring. Through past experiences, the expert can recognise the patterns of a particular situation unfolding (Klein, 2003). They are able to recognise that one area has a low probability of a penalty occurring, and thus prioritise another area for their information gathering.

Through years of developing effective situational and cognitive strategies to aid decision making, these umpires create ‘action plan profiles’ (McPherson, 1999). These ‘rule governed’ profiles are stored in long term memory, which allow for pattern recognition to occur in a particular condition. When cues are recognised as being indicative of a particular situation, an appropriate response is generated. While experts have highly tactical and refined rules for their generated responses, it is believed that novice umpires have more rudimental, simplistic and generalised responses. This is due to their limited experience with more complex scenarios so they have not yet developed more sophisticated and refined responses.
There is the potential that through creating more complex scenarios for novices to be exposed to through video-based training, this may offer the opportunity for the development of more refined ‘action plan profiles’, and therefore help solidify the decision making heuristics for levels of competition that they have not yet been exposed to in real games.

**Decision Communication and the Perception of Fairness**

The ambiguity involved in many sporting laws opens up space for individual interpretation, and is thus a key factor that needs to be considered when understanding the controversial nature of umpire decision making (Colwell, 2000). The expertise of an umpire is often determined by their external representation of fairness. In order to create a perception of fairness and impartiality, decision communication is crucial (Cunningham, Mellick, Mascarenhas, & Flemming, 2012).

In a semi-structured interview, Cunningham et al. (2012) questioned elite umpires on their beliefs on the role of communication in decision making. One of the core themes that was identified was the notion of corporate theatre. Corporate theatre captures the essence of ‘selling’ a decision to the wider audience. The communication of clear and reasoned explanations behind a decision is not only important for the players, but for spectators, coaches, and other officials who may critique and analyse the game. The importance of communication becomes increasingly vital when the decision is novel, or does not occur readily throughout the game (Cunningham et al., 2012). In circumstances where there is excessive dissent from players (often through confusion), the umpire may choose to expand on their decision and provide a rationale. This helps communicate to the players that a specific behaviour will not be tolerated, and thus attempt to stop the behaviour throughout the game. When an umpire makes an attempt to communicate and provide a rationale to the players, this can increase the perception of the umpire as being competent and fair.
In netball, due to the speed of the game, there is often little time for the umpire to stop and verbalise a rationale behind a decision. Within the netball rule book, captains are given the opportunity to approach the umpire during an interval to clarify the rationale behind a decision. The more advanced the umpire is at being able to verbalise their declarative ‘knowledge’ (e.g. knowledge of specific laws), the more competent, and fair they will be perceived as. Therefore, even though deliberative, rational thought is not expected during game play, the ability to communicate decisions effectively during stoppages is an important factor in developing perceptions of expertise.

Concluding Remarks

With the sheer volume of decisions made during sporting competitions such as netball, the expectation that every decision will be ‘correct’ is unrealistic. However, when the difference between winning or losing comes down to one critical decision, the expectation of decision making accuracy is expected and demanded by players, coaches, and spectators. In these critical situations, it is yet to be determined if the best decision making strategy is to make judgements based on strict laws, or to allow umpires to rely on their intuition to determine the ‘right’ decision. Whether umpires are too literal, or too liberal with their interpretations of the law, their judgements will always be subject to critique.

The pursuit of decision making excellence and expertise requires varied and complex experiences, coupled with an in-depth understanding of the application of the written laws to each of these complex scenarios. The more decision makers expose themselves to a variety of scenarios, the more likely they are to develop mental models for how to ‘best’ respond. Further exploration of the processes involved in expert umpires’ decision making is needed. If researchers continue to adopt multi-dimensional experimental protocols that examine both gaze
behaviour and the corresponding rationale and verbal responses, the perceptual and cognitive correlates to decision making accuracy will be better understood.

The footage used in decision making experiments plays an important role in creating a more realistic decision making environment (Larkin et al., 2014). Understanding how to replicate the complex decision making environments involved in sport is crucial for the development of future research in this field. In the current experiment the footage was recorded from an umpire perspective (wearing a head mounted camera), with the attempt to create more ecologically valid footage typical of an umpire’s usual in-game positioning. While the umpires reported the footage as being an interesting perspective to see the game from, the clarity or vividness of the footage did not accurately reflect a typical game.

The umpires were asked to rate the clarity of the footage in comparison to their experience as a live umpire. A score of one meant the images were very unclear, and a score of seven meant the images were perfectly clear. The footage was rated $M=3.5$, $SD=0.97$. This lack of clarity may have influenced the umpires’ ability to pick up cues as they normally would in a real game context. One of the reasons for this lack of clarity was due to lighting issues in the experimental testing room. When the room was dark, the quality of the projected image was much better. However, when the testing room was in this state, the umpires’ pupil became too large, thus degrading the eye-tracking software’s ability to track the pupil. We controlled this through using a room with no natural light, which removed the unpredictably of sunlight, while allowing for better control of the pupil size with internal free-standing lights. While neither the pupil size or the quality of the image were at their ideal, a balance had to be made so that the light was bright enough to shrink the pupil to the appropriate size, while the room was dark enough so that the footage could be seen clearly.

The distinction between the “letter” and the “sprit” of the law does not have to be viewed as an ‘either/or’ phenomenon. Accurate decision making requires access to deliberate,
rule based knowledge derived from law, but also the humanistic qualities of interpretation and judgement that are unique to each context. Once we acknowledge that “knowing how to decide accurately is a pre-requisite for deciding adequately” (Schweizer et al., 2011, p. 431), the entrenched cynicism directed toward the umpire’s role may diminish.

While this current study did not provide evidence to suggest that expertise is distinguishable at the perceptual level, access to more advanced technology to create better quality umpire-perspective footage, as well as access to a more up-to-date eye-tracking system may have influenced the outcome of these results. However, as suggested there are wider issues concerning the lack of the contextual integration in video-based tasks, which could have had more of an affect on the outcome of decision making accuracy.

What we can derive from this current study, is that a valuable starting point for the development of umpire expertise, would be to develop strategies which allow novice umpires to examine the content of their intuitions. The development of the knowledge behind intuition is an important factor in unlocking the key to more accurate and well-reasoned decision making in the fast-paced complex environment of sport.
References


Appendices

Appendix A
Game-Specific Scenarios: Question Sheet

1. From a Penalty Pass on the circle edge, Black C feeds the ball to Black GA. As GA moves forward to receive the pass White GD follows, staying right behind Black GA. As GA receives the pass she swings around, slightly bumping into White GD who stumbles backward.

2. White WA feeds the ball to White GA who lands in the shooting circle. From the correct distance Black GK reaches forward to defend the shot. GK places her hand on the ball causing GA to readjust her shot.

3. White GK leaps into position to defend an attempt at goal. She is defending from the correct distance when she leans in and looses balance slightly. While still maintaining the correct distance she jumps up to attempt to block the shot, landing within 0.9m with her hands still over the ball.

4. White GS runs forward to receive a pass from White WA at the circle edge. She quickly feeds the ball back to White WA to gain a better position. Black GD and White GS are then contesting for position and GD uses her elbow to push GS off her.

5. White GD runs in to defend an attempt at goal. She takes off from the ground at the correct distance and launches herself upward and forward to defend the shot. White GD lands crouched in front of the shooter within 0.9m.

6. White GS lands on her right foot, and then places her left foot in front of her right foot. She then lifts her right foot off the ground, stepping onto her left foot. In the meantime, Black GK is positioning herself to defend the shot from behind. The space between the GS’s left foot and the GK’s front foot is 0.9m.

7. White GK is defending from the correct distance. As she leans in White GD grabs her dress to prevent her from falling forward. Her hands are right over the ball making it difficult for Black GA to shoot. The ball is released from the shooters hands, and then GD lets go of the GK’s dress, making her fall forward off balance.

8. White GD runs forward to receive a pass in the middle of the court. Black GA reads this play and also runs across to the middle of the court. As GD lands (catching the ball), GA lands in front of GD within 0.9m and she raises her arms to defend the ball. GD then steps off her grounded foot, thus shortening the distance between the two players, positioning them chest to chest. GD finds it difficult to pass the ball.

9. White GA receives a pass from White C in the goal third. White C then drives towards the goal circle to receive a pass back. Black C holds her arm across White C’s body to stop a pass, resulting in White C running into Black C’s arm.
10. From a Penalty Pass, Black GA feeds the ball to Black GS. Black GS and White GK are jostling for position, and bump into each other slightly in the air. Black GS catches the ball and White GD lands a bit off balance. Black GA shoots for goal.

11. White GD is defending Black GS from the correct distance. She jumps to defend the shot and lands within 0.9m. Black GS times her shot so that as White GD lands, she releases the ball. White GD moves quickly out of the way, and Black GS is unsuccessful in her attempt to score a goal.

12. From a penalty pass or shot, GA sets up to take a shot at goal. Defending from the correct distance, GD leans her chest forward, with her arm outstretched moving downwards. Simultaneously GA raises the ball in her upward shooting action. GD’s hand makes contact with the ball causing a brief pause in GA’s shooting action.

13. From a centre pass White GA receives the ball. She turns and looks down court, and feeds a long, high ball into White GS. Black GK is positioned in front of White GS, and when they contest the ball in the air, White GS reaches over the top of GK to try and gain possession. GK gains possession of the ball, and falls awkwardly to land.

14. Black WA drives onto the circle edge to receive a pass. She looks into the goal circle to make the next pass. You play advantage as White WD is obstructing the pass. Meanwhile Black GA is attempting to position herself to receive the ball. White GD is marking GA within 0.9m, with her arm outstretched; blocking the path the ball would travel between Black WA and Black GA, therefore, making it difficult to pass.
Appendix B

T-test Tables for Correct and Incorrect Decisions

**Visual Search Behaviour**

### B1) Contact Scenarios

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### Fixation Locations

#### B3) Contact Scenarios

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**Ball**
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- Correct: 29 19.84 20.96 3.89 .733 34 .468

**Body A**
- Incorrect: 7 14.72 7.70 1.43
- Correct: 29 17.14 8.41 3.18

**Feet A**
- Incorrect: 7 0.60 1.58 0.60 -0.732 34 .469
- Correct: 29 23.93 13.01 2.42

**Body D**
- Incorrect: 7 24.41 14.46 5.47 .086 34 .932
- Correct: 29 0.00 0.00 0.00

**Arms D**
- Incorrect: 7 17.14 8.41 3.18
- Correct: 29 0.17 0.91 0.17

**Feet D**
- Incorrect: 7 3.02 5.16 1.95 1.280 6.658 .243
- Correct: 29 6.45 2.43 0.48

**Court**
- Incorrect: 7 16.04 16.26 3.02 1.303 34 .201
- Correct: 29 14.46 13.17 2.45

**OA**
- Incorrect: 7 10.66 7.24 2.74 -0.731 34 .470
- Correct: 29 14.46 13.17 2.45

#### B4) Obstruction Scenarios

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**Ball**
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- Correct: 50 25.62 23.69 3.35

**Body A**
- Incorrect: 29 6.89 11.76 2.18 2.10 33.25 .04
- Correct: 50 2.10 4.69 0.68

**Arms A**
- Incorrect: 29 0.00 0.00 0.00
- Correct: 50 0.22 1.07 0.15

**Feet A**
- Incorrect: 29 14.61 15.40 2.86 1.06 77.00 .29
- Correct: 50 4.43 8.10 1.15

**Body D**
- Incorrect: 29 11.23 12.51 1.77
- Correct: 50 4.43 8.10 1.15

**Arms D**
- Incorrect: 29 6.45 12.43 2.43
- Correct: 50 4.44 7.77 1.10

**Feet D**
- Incorrect: 29 15.25 17.68 3.28
- Correct: 50 15.46 13.74 1.94
Appendix C

T-test Tables for Penalty and Non-Penalty Scenarios

Visual Search Behaviour

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## Appendix D

**T-test Tables for Positive Predictive Power**

### Visual Search Behaviour

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Appendix E
T-test Tables for Negative Predictive Power

Visual Search Behaviour

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E3) Obstruction Scenarios (NPP)

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<th>df</th>
<th>Sig. (2-tailed)</th>
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**Fixation Locations**

### E4) Full Sample (NPP)

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### E5) Contact (NPP)

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### E6) Obstruction (NPP)

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