Decision Making In Sport: Applying the Above Real Time Training Method

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Abstract

This thesis includes four main chapters that investigate the use of speeded video as a method of decision-making training. Six different video speeds were tested using a video-based decision-making task, to gain a thorough understanding of the effects of video speed on different levels of expertise in Australian football, particularly, the mechanisms which drive expert performance. The significant difference in performance between elite and sub-elite at the 1.5 speed indicated this to be a potential training speed for elite athletes.

Speeded video is a way to incorporate above real time training as a method to train athletes. This video speed was then used in a five-week training intervention for elite Australian football athletes, comparing to normal speed and no training groups. Training in above real time showed quicker and longer lasting decision-making performance improvements compared to normal speed and no training.

Eye movement recordings were also analysed on a subset of the training intervention study. This was the first study in sport to track eye movements throughout training, and results revealed that video-based training, especially in above real time, can create more efficient visual search strategies.

To further understand how above real time decision-making training can affect on-field decision-making performance, a specific notational analysis system was designed. This system separated the cognitive and physical components of decision making, to reflect a true indication of decision-making ability. Transfer was then tested from video-based training to on-field performance using this notational analysis system. Transfer was shown for both above real time and normal speed groups, compared to control. More specifically, above real

time training lead to a trend in selecting the best option more frequently. The comprehensive investigation of speeded video in this thesis provides strong support for the use of above real time training for decision making. Further, a solid platform has been presented upon which future research can be based.

Student Declaration

'I, *Megan Lorains*, declare that the PhD thesis entitled *Decision Making in Sport: Applying the Above Real Time Training Method* is no more than 100, 000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work'.

Signature Megan Lorains Date: 21st August, 2013

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List of Publications

Lorains, M., Panchuk, D., Ball, K. & MacMahon, C. (submitted). The effect of an above real time decision-making intervention on visual search behaviour. *International Journal of Sport Science and Coaching.*

Lorains, M., Ball, K. & MacMahon, C. (2013). An above real time training intervention for sport decision making. *Psychology of Sport and Exercise, 14,* 670-674.

Lorains, M., Ball, K. & MacMahon, C. (2013). Notational analysis for decision making in team sports. *International Journal of Performance Analysis in Sport. 13,* 110-119.

Lorains, M., Ball, K. & MacMahon, C. (2013). Expertise differences in a video decision-making task: Speed influences on performance. *Psychology of Sport and Exercise, 14,* 293–297.

Lorains, M., Ball, K. & MacMahon, C. (2012). Performance analysis of decision making in team sports. *Proceedings of the World Congress of Performance Analysis in Sport IX,* Worcester, England.

Lorains, M., Ball, K. & MacMahon, C. (2011). Above real time decision making in Australian football. *Proceedings of the 7th World Congress on Science and Football,* Nagoya, Japan.

Lorains, M., MacMahon, C., Ball, K. & Mahoney, J. (2011) Above real time training for team invasion sports skills. *International Journal of Sport Science and Coaching, 6*(4), 537–544.

Lorains, M. & MacMahon, C. (2009). Adapting the functional overreaching principle to cognitive skills: Expertise differences using speed manipulations in a video-based decision-making task. *Proceedings of the 12th World Congress of Sport Psychology (ISSP),* Marrakesh, Morocco.

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Introduction to the Thesis

Video-based training interventions for decision making in sport involve athletes watching a series of video clips and making a decision for the player in possession of the ball. Decisions are made via a mouse-click or touch-screen, with players indicating where they would place the ball. Decision accuracy is traditionally measured by comparing responses to those of elite coaches (Lorains & MacMahon, 2009; Vaeyens, Lenoir, Williams & Philippaerts, 2007). Such training methods and simulations have been used within sport (Starkes & Lindley, 1994; Vickers, Livingston, Umeris-Bohnert, & Holden, 1999) and other domains such as military and aviation (e.g., Ward, Farrow et al., 2008; Williams & Hancock, 2006, Healy & Bourne, 2012, Vincenzi, Wise, Mouloua & Hancock, 2009) to improve decision-making accuracy.

The design of video-based training interventions and use of simulations can be difficult. The complexity in selecting appropriate video clips is a major issue; more specifically, selecting clips with suitable camera angles. Two main camera angles have been used throughout the previous research: the aerial or broadcast angle and the first-person camera angle. The more accessible of these two is the broadcast angle, because it is readily available through television and is easily filmed by researchers and coaches themselves. When selecting clips, the difficulty of the scenarios also needs to be considered. The inclusion of a subjective difficulty ratings should be included, or an item analysis post testing, to eliminate any clips that no participant scored on below chance. Another issue in the design of video-based decision-making programs is engaging the athlete and making them feel like they are making decisions in a real match situation. This difficulty in particular has gathered the most criticism among researchers (Araujo, Davids & Hristovski, 2006; Farrow & Abernethy, 2003), in that some consider video cannot elicit true behaviours because the task itself is not indicative of real performance.

Over time, however, the design and methods of video-based decision-making tools have improved to create a more ‘game-like’ feeling. Decision-making training interventions have been used to enhance athletic performance since the 1970s (Thiffault, 1974; 1980). Thiffault (1974) used static slides, and asked athletes where they would place the ball if they were in possession. This method was far from creating a training environment that made the athletes feel like they were making decisions in a real match situation. Nevertheless, this method was still useful in eliciting expert behaviours for testing.

The use of video within sport became more prevalent in the 1990s with improvements in technology. Starkes and Lindley (1994), building on the methods of Thiffault (1974; 1980), used video to assess decision-making accuracy, leading the way to creating a more ‘game-like’ feeling for decision making. Further research has used video simulations to improve decision-making performance (e.g., Ward, Farrow et al., 2008; Williams & Hancock, 2006, Healy & Bourne, 2012, Vincenzi, Wise, Mouloua & Hancock, 2009). Since the advent of using video as a more ‘game-like’ approach to measuring decision-making performance, little progress has been made in exploring new approaches or methods to assess the transfer of performance into real games, a key criterion in any sport-training program.

More recently, the method of video-based decision-making training has been challenged, despite the clear benefits (Lorains, Ball, MacMahon & Mahoney, 2011; Starkes & Lindley, 1994). Video-based decision-making training is low cost and simple to set up, minimal equipment is needed, it can involve all players—fit or injured, coaches do not need to be present during training and video-based training is not physically taxing and, therefore, can be effectively incorporated into a normal training schedule. Despite these benefits, one school of research describes its usefulness is restricted, in that true behaviours are not elicited because the tasks, with responses such as a mouse-click, are not representative of real-world tasks (Araujo et al., 2006; Farrow & Abernethy, 2003).

An alternative to the traditional video-based approach with mouse-click responses, perception-action coupling, has been employed for decision-making assessment. In this approach, athletes are asked not only to decide on an action, but also to carry out the intended movement. The results from this line of research suggest that decisions may not always be altered, when the skill is physically carried out (Williams, Ward, Smeeton & Allen, 2004), yet it the effects may be stronger when they do, compared to a mouse click or verbal response (Mann, Janelle, Williams & Ward, 2007). Researchers (Dicks et al., 2010) consider that due to a person's considerations of their physical ability or that of their teammates and even their opponents, their decision making will change between carrying out the decision or using a mouse-click to make a decision (Dicks et al., 2010). The perception-action approach, while effective, negates many of the benefits of video-based methods. For instance, with perception-action coupling, injured players cannot participate, and this method of training is in addition to an athlete's already physically taxing training schedule. The equipment, cost and personnel required is much greater for perception-action training methods compared to video-based training.

Considering the debate between video-based decision-making training and the perception-action coupling method, a gap has been left in the research, leading to a major question yet to be answered: how can we more effectively train sport decision making in a 'game-like' environment while maintaining the benefits of video-based training? There are three main phases this research uses in answering this question.

First, in this thesis, the Expert Performance Approach (EPA) (Ericsson & Smith, 1991) was used to differentiate between expert and novice decision-making skill on speeded video. Above Real Time Training (ARTT) places a participant in a simulation that functions faster than the normal environment. ARTT has been employed as a process-tracing method for expertise, in order to understand what mechanisms are in use during such manipulation.

Previous research that has enforced time pressure on skills or encouraged athletes to choose the first option they see (Beilock, Bertenthal, McCoy & Carr, 2004; Hepler & Feltz, 2012; Johnson & Raab, 2003) suggests that experts perform with a higher level of automaticity. Elite athletes can do more with less information, as shown in previous spatial and temporal research (Muller, Abernethy & Farrow, 2006). Muller and collegues showed that the elite cricketers can use advanced and specific (or limited) cues to perform accurately. If this is the case, it is expected that experts may also be able to not only function, but also function well when induced to process faster, as they can use specific cues and limited information..

Further, part of using the EPA could involve eye movement tracking to provide an insight into the real time visual behaviour of cognitive processes for decision making (Henderson, 2011; Raynor, 1998). Eye movement tracking have previously been used as a process-tracing method for expertise, and more specifically, expertise in decision making (Dicks et al., 2010; Roca, Ford, McRobert & Williams, 2011; Vaeyens et al., 2007). These studies used eye movement tracking method to trace the process of expertise in decision making in in situ sporting scenarios. Process tracing used methods such as these to highlight information about the mechanisms of elite performance that are most important (Ericsson, 2006). Results of these studies support Abernethy's (1988) findings that visual search strategies of elite athletes exist because they have greater contextual knowledge and experience to only tend to the relevant cues in a given stimulus.

Helsen and Starkes (1999) tested elite, sub-elite and regional level soccer players on soccer-specific filmed scenarios, measuring decision accuracy and time, search rate (the number and duration of fixations) and fixation location (time spent fixating on various areas of the field, i.e., offensive player, ball and defender) and found that experts used significantly fewer fixations to gain information to make decisions.

Similarly, Vaeyens et al. (2007) used these methods and highlighted the usefulness of investigating eye movements. Results revealed that the more successful decision makers spent more time fixating on the player with the ball, alternating more between that and other areas of the field. While these findings are valid, there is no research to date that tracks visual search behaviours throughout training (with the exception of Sailer, Flanagan & Johansson, 2005). Rather, it has only been used to elicit expert-novice differences (Helsen & Starkes, 1999; Roca et al., 2011; Vaeyens et al., 2007), leaving a large gap in the research concerning the changes in visual search behaviour as a result of video-based decision-making training. This gap identified provides scope for this thesis to investigate what occurs in this area, when measured. The findings discussed may lend solid evidence for future research to build upon and further investigate the findings.

More specifically, a gap in the research concerns how speeded video may alter visual search strategies. It is hypothesised that due to the speeded nature of the video, visual search strategies will be forced to become more efficient, if accuracy is to be maintained or improved. This thesis specifically investigates this aspect of performance. With any research using gaze behaviours, however, it is important to consider the difficulty in equating fixation durations with attention. Simply, it is difficult to reliably infer that cognitive processes can be fully explained by gaze behaviours, yet it is one method to track the cognitive processes that may contribute to attentional resources of experts.

The second phase addressed in answering the question ‘how can we more effectively train sport decision making in a “game-like” environment while maintaining the benefits of video-based training’ is by employing ARTT to provide a more ‘game-like’ simulated environment for making decisions. ‘Game-like’ refers to the level of similarities between the real match situation and the simulated environment. ARTT has been successful in the aviation field (Guckenberger, Uliano & Lane, 1993; Kolf, 1973, Vidulich, Yeh & Schneider, 1983). An example of successful ARTT (Vidulich, Yeh & Schneider, 1983) involved training air traffic controllers to direct an aircraft through a single turn, to intercept at an exact point in time. Two groups received one three-hour training session. The first group was trained with a simulated plane travelling at 260 knots (real time) and completed approximately seven to nine trials per hour. The second group trained with the plane travelling at 5200 knots (20 times above real time) and completed approximately 72 to 80 trials per hour of training. When post-tested at real time, the second, ARTT group, was more accurate at intercepting the point. Kolf (1973) proposed that ARTT may provide a more precise feeling and replicate the demands of the 'real' experience; this was successfully implemented for fighter pilots.

More recently, ARTT has been applied in the sporting domain. Lorains and MacMahon (2009) tested the decision-making performance of elite, sub-elite and novice participants in normal and 1.5 times above real time video speeds. Elite and sub-elite groups performed significantly more accurately on both speeds compared to novices, and the elite group performed better than the sub-elite in the fast speed condition. Anecdotal evidence from both the aviation (Kolf, 1973) and sporting domains (Lorains et al., 2011) state that ARTT provides a more 'life-like' and 'game-like' experience for decision making. Given this information, ARTT presents as a practical training method for enhancing the fidelity of video-based decision-making training. This claim of higher fidelity creating a more 'game-like' simulation is untested in the research discussed. This is why it is an aim of this thesis to provide empirical evidence to support the findings of this research, and previous (Kolf, 1973; Lorains & MacMahon, 2009).

Fidelity is how comparable a simulated environment is to the real thing (Hays & Singer. 1989). Fidelity can be further broken down into specific types. Stoffregen, Bardy, Smart, and Pagulayan (2003) define *physical fidelity* as how the simulation looks compared to the real thing, and *psychological fidelity* or *experiential fidelity* is how the participant perceives the simulation and how life-like they believe it to be. The aim of this thesis is to improve the psychological/experiential fidelity for decision-making simulations. As a result of enhanced fidelity, it is hypothesised that because the training environment will feel more like the real match environment, those trained in above real time will be able to improve performance faster and retain those improvements for a longer period of time, as compared to normal or control groups.

The third aspect of answering the question of how to best train decision making using video incorporates the measurement of transfer or success of the video-based decision-making training intervention in a match situation. While ARTT may be an appropriate manipulation for training decision making, it is just as important to be able to measure the transfer of any performance improvement into match situations. Previous research has included measures of transfer in their research designs, (Farrow, Chivers, Hardingham & Sasche, 1998; Williams, Ward, Knowles & Smeeton, 2002, Gabbett, Rubinoff, Thorburn, & Farrow, 2007), although it has mainly been testing of transfer of aniticipation skills of athletes, rather than testing and transfer of decision-making accuracy performance. Starkes and Lindley (1994) state that transfer tests should be easy to administer and capture the complex nature of the task. This is often an aspect of research that fails to be included, due to difficulty in the design and measurement.

To date, little decision-making research has included a specific decision-making analysis notational analysis system. This leaves a large gap in the research, given the increasing importance placed on decision making by coaches and researchers. Bruce, Farrow, Raynor and May (2009) is an example of the minimal research that has attempted transfer tests for decision-making training. Bruce et al. (2009) based decision accuracy of netball athletes on the outcome of the physical skill. This raises the important question: was it a poor decision or poor execution that produced the negative outcome? While the two aspects are important to decision-making performance, it is vital to be able to separate the physical skill set and cognitive aspects of decision making, a feature of this research.

The aim of this thesis was to understand how we can effectively train sport decision making in a 'game-like' environment while maintaining the benefits of video-based training. This was investigated by eliciting expert-novice differences using speeded video, designing a training study and employing eye tracking methods to further understand the mechanisms of elite performance throughout training. The use of speeded video was revealed as a reliable method to increase the fidelity of video-based simulations for elite athletes. By increasing the fidelity, greater transfer was shown into real game situations, determined from the use of a specifically designed decision-making notational analysis system.

This thesis includes four main chapters reporting the main research findings. The first chapter presents the study from Lorains, Ball and MacMahon (2013). This chapter uses speeded video and the EPA to elicit expert-novice differences, which was the first step in exploring the use of speeded video for decision making. Elite, sub-elite and novice Australian football (AF) athletes were tested for decision accuracy on a range of video speeds. The results of this chapter highlight the expert-novice differences using speeded video, and shows that this manipulation can differentiate between elite and sub-elite performance. The chapter discusses how elite athletes outperformed their lesser-skilled counterparts possibly due to their ability to perform with a higher level of automaticity and a superior level of processing efficiency, both key characteristics of expertise. Processing efficiency of information the speed that mental processes can occur, for example, memory retrieval or mental comparisons. (Lachman, Lachman & Butterfield, 1979). This can be measured simply by reaction time, or in the case of this thesis, the ability to perform accurately in high speed situations. Chapter One also discusses an optimal video training speed as identified by results of a seven-point likert-scale that followed each clip, asking for a 'game-likeness' rating for making decisions.

The optimal video speed refers to which video speed the participants rate as feeling most 'game like'. The aim of using the optimal training speed is to create a higher fidelity simulation to aid in the improvement of decision accuracy. This video speed is then applied as the optimal speed within Chapter Two.

Chapter Two presents the study from Lorains, Ball and MacMahon (2013). This chapter used the optimal video training speed of 1.5 times normal speed, indicated as optimal from the findings of the first chapter, in a five-week training intervention. The idea that ARTT provides a higher fidelity simulation is also discussed within this chapter. The design of this research was aimed at providing a more 'game-like' training environment while maintaining the benefits of video-based training. Following the five-week training intervention, the results highlighted that when athletes were trained in above real time, they improved in accuracy faster than those trained in normal time. While both groups improved as a result of the video-based decision-making training, the above real time group achieved faster and longer lasting results, as indicated by retention testing performances. There is limited discussion of the transfer testing notational analysis system and results in this chapter. A more detailed explanation and discussion is provided in Chapter Three.

Chapter Three presents the work in Lorains, Ball and MacMahon (in press). This chapter uses a specifically designed decision-making notational analysis system to measure performance transfer from the video-based decision-making training intervention to on-field performance, as discussed earlier. Further, it is used to measure individual game performances. The notational analysis system is used to measure these aspects on a subset of participants from the training intervention. The benefits of this notational analysis system compared to previous research are discussed, particularly in the separation of the cognitive and physical components of decision making. Logistical limitations are discussed, relating to small sample sizes and issues around measuring live game performance due to team selections, injuries and player match-ups. Last, the benefits of this system are also discussed, being that it was designed with much flexibility to be applied to a range of different sports and performance arenas.

Chapter Four presents the work from Lorains, Panchuk, Ball and MacMahon (2013). The eye movement data presented here were collected throughout the video-based decision-making training intervention (see Chapter Two). A discussion on the lack of research that has tracked eye movements throughout training is presented in this chapter. The discussion of results is limited due to very few significant findings, most likely because of the small sample size used. The main finding of this chapter is that visual search strategies will change throughout training; more specifically, training in ARTT will lead to athletes spending more time fixating on the best option available. Future research opportunities are also outlined within the discussion of Chapter Four.

Chapter Five is a general discussion of the whole thesis. This chapter combines the results of the data presented in each study and discusses them in a theoretical context. The practical implications for researchers and coaches are also discussed, followed by specific future research opportunities the results from this thesis have formed. Final conclusions are included at the end of this chapter. These conclusions reiterate the main findings of the thesis.

Chapter Six presents this thesis' contributions to knowledge and literature in the area of decision-making in sport. The main strengths of the research design are stated and specific gaps in the literature and research opportunities are highlighted. Future research opportunities and practical implications for coaches and researchers are also discussed, in the broader context of the literature.

References and appendices follow the main chapters. Appendices include all ethical consent and information forms provided to research participants. A letter of support is included, followed by an example of the feedback provided to participants following the training intervention. This section concludes the thesis.

Chapter 1: Expertise Differences in a Video Decision-Making Task: Speed Influences on Performance

(From: Lorains, M., Ball, K. & MacMahon, C. (2013). Expertise differences in a video decision-making task: Speed influences on performance. *Psychology of Sport and Exercise*, 14, 293–297.)

The intrigue of watching expert performers excel in their domain has sparked decades of research dedicated to understanding the mechanisms underlying such performance. While expert performance may be seen in a variety of domains (e.g., medicine, the military and academia), the elements of sport provide an ideal platform for scientists to examine human behaviour and expert performance in a dynamic, ever-changing environment, often under stressful and constrained conditions.

Ericsson and Smith (1991) proposed the EPA as a theoretical framework for understanding how elite performers function in a given domain. This approach applies three stages to the study of expertise. The first stage is to capture expert performance through laboratory testing or field testing. The expert-novice paradigm is used in this first stage to aid in identifying expert performers. Field or laboratory testing is used to elicit the differences in expert and novice performance. The second stage is to use process-tracing methods (e.g., eye movement recordings, verbal reports and film occlusion) in the design of a representative task to establish which mechanisms lie beneath the expert performance. At this stage, the goal is to understand how experts perform better than novices in the target skill. The third and final stage of the EPA is to examine the acquisition of the identified characteristics of expertise. Retrospective training history profiling or learning studies and training interventions can be used at this stage.

The EPA has contributed to our understanding of expertise within sport. Research that has focused on capturing the nature of the expert advantage has identified that experts possess superior perceptual-cognitive skills, such as pattern recall (Abernethy, Baker & Cote, 2005; Baker, Cote & Abernethy, 2003; Gilis, Helsen, Catteeuw & Wagemans, 2008), anticipation (Abernethy, 1994; Muller et al., 2006; Williams, Ward, Knowles & Smeeton, 2003) and decision making (Abernethy, 1996; Lorains & MacMahon, 2009; Starkes & Lindley, 1994). MacMahon and McPherson (2009) suggest that pattern recall and anticipation are secondary, and contribute to decision making as the more primary skill. Nevertheless, all of these skills have been attributed to a higher level of automaticity in experts compared to novices (Beilock et al., 2004; Beilock, Carr, MacMahon & Starkes, 2002; Fitts & Posner, 1967).

In applying the EPA to the dynamic, ever-changing environment of sport, Williams and Ericsson (2005) draw attention to the importance of realistic simulations at the first and second stages to properly elicit expert-novice differences and understand the key characteristics of expertise. This is particularly the case for decision making. Williams and Ericsson (2005) highlight the attempts that have been made to create measures of athlete performance in-situ (high-speed video, liquid crystal occlusion glasses, digital video technology, satellite and micro-chip player and ball tracking technology). However, few advances have been made in creating a more realistic video-based decision-making simulation.

Research that examines decision making in sport has shown that it can be a complex skill to capture in a laboratory, particularly using video-based tasks (e.g., MacMahon, Starkes & Deakin, 2009). There are some process-tracing methods that have been successful. For instance, the occlusion paradigm alters video footage temporally and spatially (e.g., Muller et al., 2006). This paradigm has been used to identify the influential cues that elite performers use, and also more generally, that experts can ‘do more with less’ (see Williams, Ford, Eccles & Ward, 2011 for a more in-depth review of the acquisition of perceptual-cognitive skills). Similar to the manipulations used in the occlusion paradigm, the speed at which video is played presents a method to trace the influence of processing speed on performance. If athletes can do more with less information, it is hypothesised that they will also be able to not only function, but function well when induced to process faster.

Glockner and Betsch (2012) suggest that decisions are made faster when all information is present, versus showing only vital cues. The researchers state that taking out information may lead to confusion and longer time to make decisions, as participants are trying to 'fill in the blanks'. Providing complete information, but increasing the speed of presentation encourages processing efficiency, while still showing all the vital cues.

Fitts and Posner (1967) suggest that elite athletes perform with a higher level of automaticity than do novices, with little need for thought to the detailed aspects of the skill. Although the concept of automaticity is applied generally to physical skills (e.g. Beilock et al., 2004; Beilock et al., 2002), it has also been used to explain cognitive skills, such as decision making. In sport, Johnson and Raab (2003) showed that applying time pressure to decision making may help decision accuracy, rather than hinder it. They tested this for elite level performers in handball. Participants were told to make their decision as quickly as possible, adding time pressure to their decision. They found that athletes were more accurate when they chose the first option they generated. These results suggest that time pressure may force athletes to perform more automatically, aiding their performance. More recent research supports the position that when athletes choose the first option that they generate, more instinctively and with a higher level of automaticity, it results in a higher quality decision (Hepler & Feltz, 2012).

While elite athletes do not always operate in an automatic fashion, research supports the understanding that it is a key characteristic of elite performance. This may depend on the type of decision being made or particular situation they are in, to allow for an intuitive or deliberate decision. One individual may use both, and this could be manipulated through clip selection and difficulty. This research, however, is aimed to investigate how the use of speeded video may aid in performance.

Speeded tasks may aid in processing efficiency as the nature of the task forces experts to perform with a high level of automaticity. The use of speeded manipulations has been previously applied in sport. For example, Gilis, Helsen, Catteeuw, Van Roie & Wagemans (2009) used speeded computer simulations to assess the decision-making performance of officials. The use of game video, however, creates more life-like stimuli. For example, Lorains and MacMahon (2009) used speeded video to create a more 'game-like' decision-making task in which elite, sub-elite and novice athletes were tested using normal and fast speed video (1.5 speed) to assess decision-making accuracy. This manipulation was utilised to decrease the time for information processing, thus forcing participants to perform more automatically (processing only the critical cues from the stimulus), as they would in a real game situation. Results from the video-based decision-making task revealed that the elite athletes performed more accurately on the fast speed video than on the normal speed video. The performance of the sub-elite and novice athletes declined with speeded video. This indicates that processing speed differentiates skill levels, given that the same cues were present in all videos; however, increased speed forced faster and/or more efficient processing.

Building on the work of Lorains and MacMahon (2009), the current research follows the investigative lines of the first two stages in the EPA and makes use of a video-based decision-making task to assess performance at, and perception of, different video speeds. Using the proposed process-tracing method of speeded video, a video-based decision-making task was used to test accuracy for elite, sub-elite and novice athletes. The aim was, first, to highlight which video speed elicits superior performance for each group and, second, to investigate which video speed athletes perceive to be most 'game-like' for decision making. It was predicted that the elite athletes would perform poorly at slow speeds, as this would de-automate their behaviour. It is expected that having elite athletes perform in a slow speed video simulation, that they would be unable to perform with a certain level of automaticity, as the stimulus would be too slow. On the contrary, it is expected that performance would improve as the video speed increased. The inclusion of various speeds was purely investigative. Previous research (Lorains & MacMahon, 2009) used 1.5 speed, and this was based on aviation and ARTT research. This current investigation of an array of speeds provides more insight into the performance at different speeds, compared to just one single speed.

This prediction was also supported by the work of Lorains and MacMahon (2009), where elite athletes improved decision-making accuracy when tested on videos at 1.5 times normal speed. It was also expected, based on anecdotal evidence from aviation domains (Guckenberger et al., 1993; Kolf, 1973) and sport (Lorains et al., 2011), that athletes with experience in AF, regardless of skill level, would perceive faster video speeds as more ‘game-like’. This is due to the fast nature of the sport. Anecdotal evidence (Lorains et al., (2011) reported that athletes felt like the game speed was fast when they were in it, therefore the faster video speeds were indicated as being most like a game situation. In the reverse, the normal speed was considered slower (Guckenberger et al., 1993; Kolf, 1973; Lorains et al., 2011). This is an important aspect of the design, as the aim is to find an optimal speed for training, to create a more ‘game-like’ simulation.

Method

Participants

Eighty-five males aged between 18 and 30 years, with a mean age of 23.23 years (*SD* = 3.43) across three groups (elite, sub-elite and novice) participated in this study. The elite group comprised 45 athletes with a mean age of 22.19 years (*SD* = 3.10) who had been playing/training in the Australian Football League (AFL) for a minimum of one year (mean time playing at this highest level in the sport = three years). Sub-elite participants were 21 Victorian Football League (VFL) reserve-level players, with a mean age of 20.34 years (*SD* = 3.44). This group had a mean time playing at this level of 4.6 years (*SD* = 3.1). For both elite and sub elite groups, an even mix of positions was apparent, as whole squads were tested. The novice group consisted of 19 participants with a mean age of 22.68 years (*SD* = 4.05). The novice group had no experience in playing competitive AF. They were recruited from undergraduate university classes and the wider community. The University Human Research Ethics Committee provided ethical approval. All participants volunteered their time and provided informed consent prior to testing sessions.

Equipment

The videos used in the AF decision-making test were sourced from a broadcast aerial camera view of AFL game-day footage. These included video clips of the team in possession of the ball and moving into attack (inside 50 plays), kicking the ball out from defence (kick-ins) and playing throughout the midfield. The clips featured a range of AFL teams in possession of the ball. Each video clip was edited within Adobe Premiere Elements 9, using the time stretch feature to increase the speed of each clip to 1.25, 1.5, 1.75 or 2.0 of the normal (1.0) game-day footage, or to slow it down to 0.75. Any speed lower than normal speed video was considered slow speed and those higher than normal speed were considered above real time video speed (e.g., Guckenberger et al., 1993). For example, if a normal speed clip was six seconds in duration, the above real time (ART) clip, if edited to 1.5 of that speed, was completed in four seconds.

Prior to manipulating the speed of the clips, three AFL coaches (from two different AFL clubs) independently viewed each video clip in normal speed. Each coach independently rated each clip and designated three, two or one point(s) based on their opinion of the best of the three decisions available in each clip. Where coaches differed on their ratings, the majority agreement was used. There were no clips where coaches rated completely differently, they were in agreement for each of the options for 89% of the clips, for the remaining 11% of clips, the majority agreement was used. Coaches were blind to the aim and participants involved in the study.

The presentation and data collection were completed through the experimental psychological software testing tool E-Prime v2.0 Professional. This software recorded and automatically scored each response. The testing was completed using individual laptops and a mouse-click to record responses.

Procedure

Each participant, sitting at an individual laptop and wearing headphones, watched 70 video clips (including 12 warm-up clips). All participants viewed the clips once in one of six different speeds. Speeds were randomly presented to participants. The maximum score possible for the test was 174 (based on scoring three points for each of the 58 test clips).

In each clip, the video was paused at the critical decision point: prior to ball release. At this point, participants heard a 'beep' and used the computer mouse to indicate on the screen where they would target their kick or handball. The options were to target another player, an area of the ground, between the goal posts, a space for the player to run on to or to play-on themselves (click on the player). Participants were told to make their decisions as quickly as possible once they heard the first beep. The aim of the beeps was to induce time pressure on decisions. After the first beep, participants had three seconds to respond; warning tones for time running down commenced at two seconds after the initial beep. After three seconds, responses were not recorded.

The performance measures used were decision accuracy and decision time. Decision accuracy was measured by comparing participants' responses with coach ratings of the video clips. Any responses outside the coach-identified options, or outside of the three-second response period, received zero points. Decision time was measured in seconds, taken from the first beep (when the video paused) to participant response via mouse-click. There was no start point for the mouse curser, so participants were free to track movement on the screen with the mouse.

Following each video clip, the elite and sub-elite groups were asked to rate how ‘game-like’ that particular video speed had felt. Unaware of the actual speed, the participants used a seven-point scale to rate how ‘game-like’ the speed felt. The screen showed seven boxes in chronological order. One, two and three indicated ‘too slow’ (nothing like the pressure they feel in a real game). Four indicated ‘very game-like’. Five, six and seven indicated the speed was ‘too fast’ (nothing like the pressure they feel in a real game). The novice group did not respond to this question; they had no AF game experience and, therefore, no reference point for what feels ‘game-like’.

Data Analysis

To analyse decision accuracy results, an initial three group (elite, sub-elite and novice) x six video speed (0.75, 1.0, 1.25, 1.5, 1.75 and 2.0) mixed between-within subjects analysis of variance (ANOVA) was completed to investigate the effect that different video speeds had for decision-making accuracy for different groups. Further, a repeated measure ANOVA was run to compare within-subject accuracy performance for the elite group across each video speed.

Decision time was analysed using a three group (elite, sub-elite and novice) x six video speed (0.75, 1.0, 1.25, 1.5, 1.75 and 2.0) mixed between-within subjects ANOVA to investigate the effect that different video speeds had on the decision-making time for different groups.

A two group (elite and sub-elite) x six video speed (0.75, 1.0, 1.25, 1.5, 1.75 and 2.0) mixed between-within subjects ANOVA was completed to investigate how ‘game-like’ the participants perceived each video speed. A seven-point scale was used to assess this. Selecting one (1), two (2) or three (3) on the seven-point scale indicated that the participant felt it was too slow and not at all ‘game-like’. A score of four (4) indicated that it felt just like a game, and five (5), six (6) or seven (7) indicated that it felt too fast and, therefore, not at all ‘game-like’. Bonferroni adjustment was applied to all analyses to control for type I error, and effect sizes were calculated using ηp^2.

Results

Decision Accuracy

Results from the within-subject ANOVA revealed a main effect of video speed F(5, 40) = 9.37, $p < .001$, Wilks Lambda = .46, $\eta p^{2\,=}$ .54. The elite group performed significantly more accurately on faster speed video (1.25, 1.5, 1.75 and 2.0) compared with normal (1.0) and slow (0.75) speeds. Speeds 0.75 and 1.0 did not differ significantly. Speeds 1.0 and 1.25 were significantly different, $p < .001$. Accuracy scores on speed 1.25 did not differ from 1.5 or 1.75, but were significantly less accurate than 2.0, $p = .028$. Finally, there were no significant differences in accuracy between speeds 1.5, 1.75 and 2.0.

A significant interaction effect between video speed and group was found $F(10, 156) = 6.43$, $p < .001$, Wilks’ Lambda = .50, $\eta p^{2\,=}$ .292, highlighting a very large effect. This is shown in Figure 1.1. Follow-up pairwise comparisons revealed that the elite group were significantly more accurate than the sub-elite and novice groups, $p < .001$. In turn, the sub-elite group were more accurate than the novice group, $p = .037$.

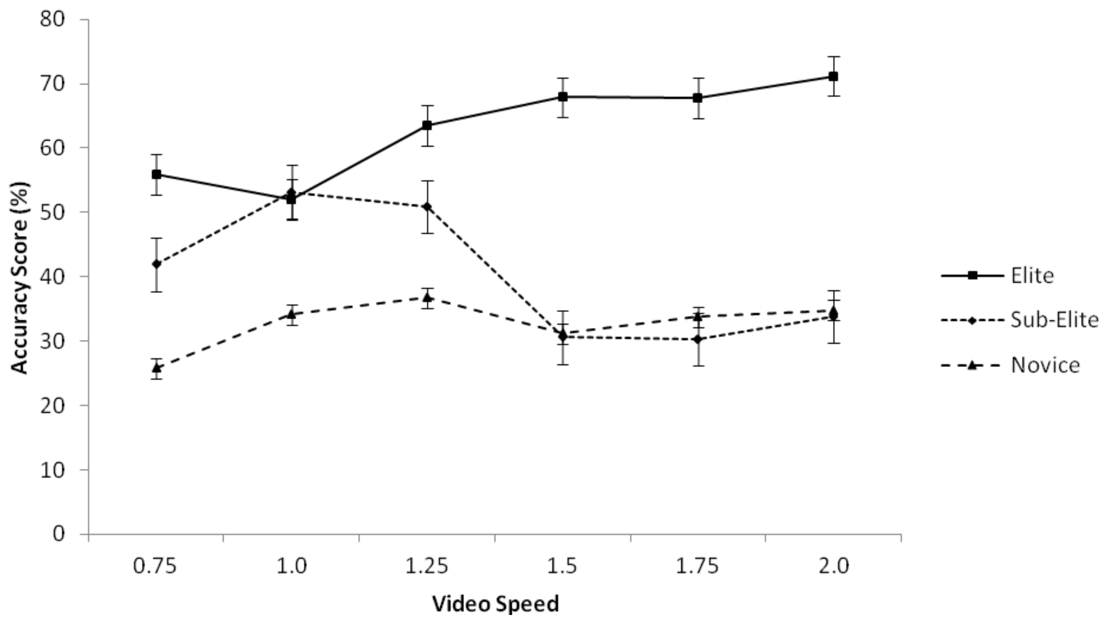


Figure 1.1: *Group by video speed interaction effects for decision accuracy*.

Post-hoc testing revealed that for the slow speed (0.75), the elite group were more accurate than the sub-elite group (p = .019), who were more accurate than the novice group (p = .027). Normal (1.0) speed showed that the elite and sub-elite groups were more accurate than the novice groups (p = .001). At the 1.25 speed, the elite group outperformed the sub-elite and novice groups (p < .001). At the 1.5 speed and above, the elite group outperformed both the sub-elite group and the novice group, who did not differ significantly from each other at any of 1.5, 1.75 or 2.0 speeds.

Decision Time

There were no significant interaction effects or main effects of group. There was a significant main effect for video speed $F(5, 78) = 2.97$, p = .017, Wilks' Lambda = .84, $\eta p^{2\,=}$ .160. Follow-up pairwise comparisons revealed that the significant differences were between video speeds 1.25 (M = 1.40, SD = 0.35) and 1.75 (M = 1.53, SD = 0.32), p = .009, with faster decisions for the former than for the latter. The relationship between decision time and decision accuracy revealed a small, non-significant negative correlation, $r = -.026$, $p = .816$.

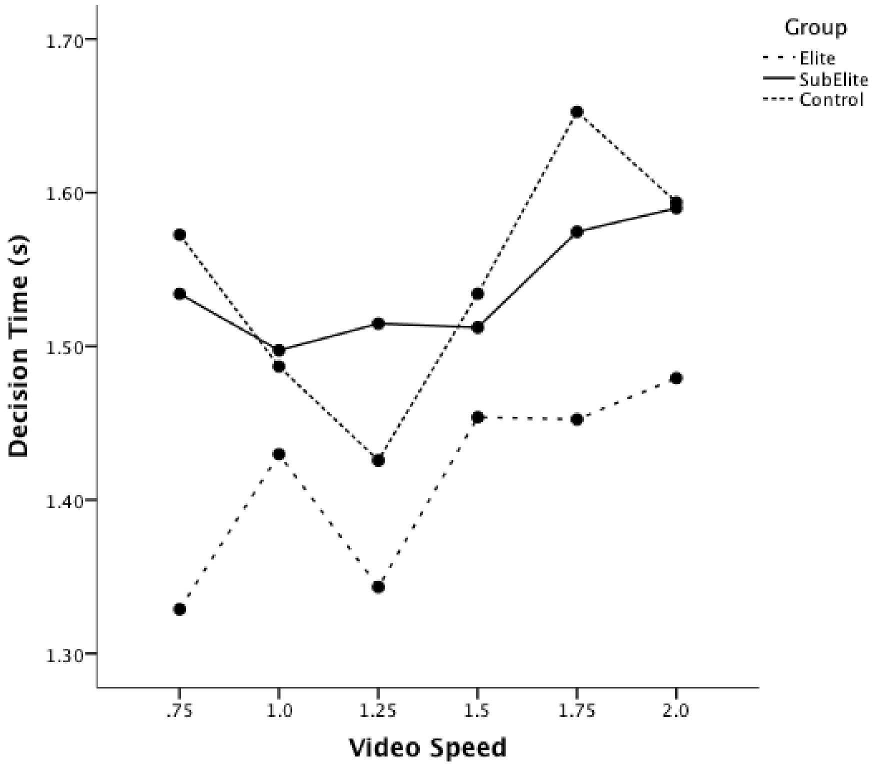
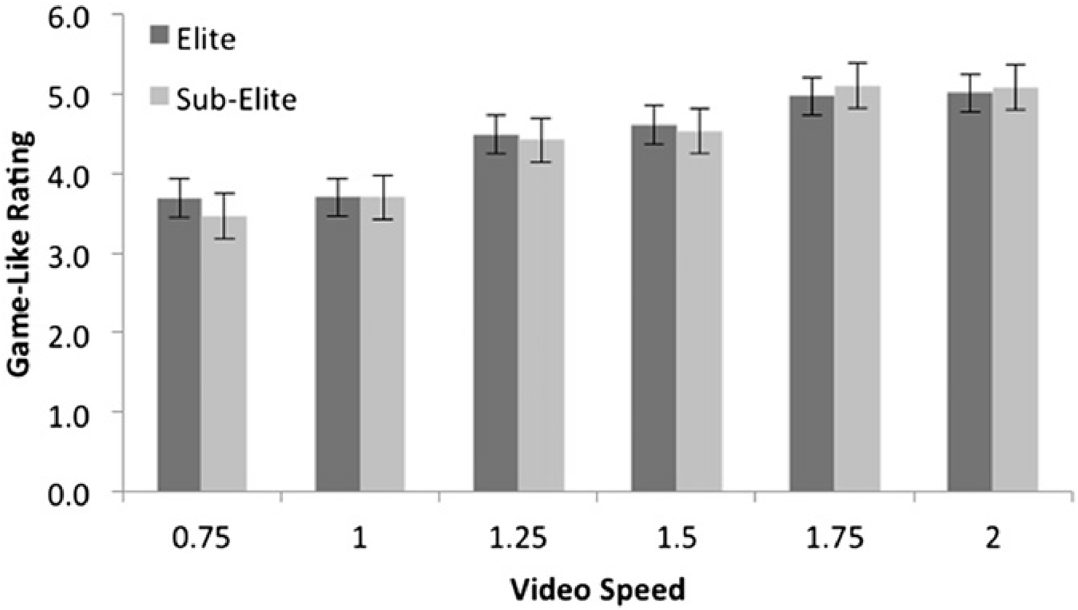


Figure 1.2: Group by video speed interaction effects for decision time.

Ratings of Video Speed for 'Game-Likeness'

There were no significant interaction effects. There was a significant main effect for video speed $F(5, 60) = 18.97$, $p < .001$, Wilks' Lambda = .39, $\eta p^{2} = .613$. Follow-up pairwise comparisons revealed that participants rated speeds 1.25 and 1.5 most 'game-like'. These two speeds did not significantly differ from each other. Speeds 0.75 and 1.0 were rated as too slow compared with 1.25 and 1.5, $p < .001$. In the same trend, faster speeds (1.75 and 2.0) were rated as too fast, $p < .001$. These results are displayed in Figure 1.2.

Figure 1.3: 'Game-like' ratings for video speed by group. Scale: 1–3 = too slow, 4 = 'game-like', 5–7 = too fast.



Discussion

This research was the first to systematicaly test performance on a range of different video speeds, to trace differences in performance amoung skill levels. As discussed earlier, Gilis et al. (2009) used speeded computer video simulations to assess decision making in officials, as well as manipulating the movement speed of defenders. This current method goes beyond this work to use speeded video as framed by ARTT research and allow further exploration of the underlying mechanisms of automaticity and processing efficiency. It has also identified speed manipulations as a method for increasing the psychological/ experiential fidelity of video-based simulations and as a training tool.

Through the expert-novice paradigm, the results of this study revealed that, overall, elite AF players have superior decision-making accuracy to that of sub-elites and novices. This finding is not new to sport expertise research (e.g. Abernethy, 1996; Lorains & MacMahon, 2009; Starkes & Lindley, 1994). However, the differences between groups based on the speed at which the videos were played are new findings, which provide insights into mechanisms underlying the expert advantage. Moreover, this research used speeded video in the attempt to allow participants to perform more automatically in a video-based decision-making task, employing a novel laboratory manipulation to simulate performance.

These results suggest that the use of superior processing efficiency may have helped experts to perform with a higher level of automaticity in this laboratory-based task. This is only one possible suggestion. Overall, elites withstood the speed manipulations well, whether faster or slower, and in fact, improved with faster video. Sub-elites were more vulnerable to speed changes. In particular, both the sub-elite and novice participants' accuracy plateued at a low level with increasing speed. Given the pattern of results changed depending on the skill level and experience of the participants, it is reasonable to conclude that increasing the speed of video increases the need for automated performance in this task.

In order to elicit true characteristics of expert performance, a task representative of the real domain is needed (Williams & Ericsson, 2005). Results showed no difference in accuracy scores between the sub-elite and elite groups with normal speed video, possibly due to the task being perceived as less representative at normal speed. Similar failure to elicit expert-novice differences in laboratory-based decision-making tasks have been shown elsewhere (e.g. MacMahon et al., 2009). Interestingly, the results of the slow speed (.75) video also elicited expert-novice differences. The elite group were more accurate than the sub-elite and novice groups. This was against the hypothesis, that the slow speed may de-automate behaviour for elite athletes. In addition to this, the elite athletes took longer to make their decisions on the slow speed. However, as predicted, the elite group's performance improved as the video speeds increased. These results suggest that speeded video elicits more representative and, thus, at the elite level, an automated behaviour, because it feels more 'game-like', a perception supported by the ratings of 'game-likeness'. Not only did elite participants improve with increased speed, but also sub-elite participants significantly declined in performance when the speeds reached 1.5 and higher. Sub-elite experience in this domain allowed them to make accurate decisions with a moderate increase in speed, up to a point. This point of difference (1.5 speed) where the sub-elite group declined in performance, compared to the elite group, would serve as a base for future reearch to examine the skill set of the sub-elite group at different video speeds throughout training. However, speeds faster than 1.5 normal speed called for a more automated skill set and their performance declined at this point. The novice group may have found the task too difficult overall, scoring extremely low on all speeds.

The secondary aim of this research was to gain information regarding which video speed had the perception as feeling most ‘game-like’ for athletes. This would aid in designing a more representative video-based decision-making task. The elite and sub-elite groups rated video speeds the same, with the 1.25 and 1.5 video speed feeling most like a real game when making a decision. The elite athletes did not show declines in performance at either of these speeds, but the sub-elite group did. This suggests that while the sub-elites perceive real games to be faster, they still may not have the processing efficiency to perform in an automated fashion.

Through increasing the speed of the video-based decision-making task, the researcher was able to gain further insight into the processes of expert performance. Elite participants may have used superior processing efficiency and automaticity to perform more accurately as the video speed increased, while the sub-elite and novice participants, lacking these characteristics, declined in performance. Using this optimal video speed may allow researchers to gain a better understanding of the mechanism of automaticity and the processing efficiency in elite athletes in decision-making tasks, although this was not explicitly tested. These findings suggest that, from an elite point of view, the video speed of 1.5 may be an optimal video training speed compared to the more traditional video-based training simulations that are completed in normal speed. The fact that the athletes themselves rated the 1.5 speed as feeling most ‘game-like’ when making decisions suggests that this form of video-based simulations provides a closer representation of real game conditions for decision making. Results also showed that 1.5 speed was the point of difference in performance for the sub-elite and elite groups. Furthermore this is supported by previous aviation research (Guckenberger et al., 1993; Kolf, 1973). The finding that elite athletes continued to improve in performance with video speed should also be a point of future research. The identification of 1.5 as an optimal training speed may only be one possibility, and should be investigating. The results presented here provide an exciting new platform for future research to investigate the use of speeded video for training purposes, because it creates a more perceived ‘game-like’ video simulation environment for both elites and sub-elites, while still maintaining the benefits of video-based training.

Chapter 2: An Above Real Time Training Intervention for Sport Decision Making

(From: Lorains, M., Ball, K. & MacMahon, C. (2013). An ARTT intervention for sport decision making. *Psychology of Sport and Exercise.*)

The training of decision-making skills of athletes is a key element to elite success (Baker et al., 2003). Researchers have shown great interest in the mechanisms that drive elite decision-making skills (e.g., Baker et al., 2003; Lorains & MacMahon, 2009; McMorris, 1997; Starkes & Lindley 1994). Starkes and Lindley (1994) were among the first to design a video-based decision-making training study. They trained athletes on both static images and video of basketball, in order to assess any differences in performance. Participants either watched video or looked at static images and indicated where they would place the ball if in possession. Results showed that video-based decision-making training was more effective for performance improvements than were static images. The authors state that by using video to train decisions, coaches can control the scenarios for specific needs, involve injured players and not increase the physical load of athletes. These are major benefits of video-based training, but they have often been dismissed in favour of perception-action coupling, which is thought to create a more ‘life-like’ environment for decision making (Araujo et al., 2006; Farrow & Abernethy, 2003).

The current research explores the potential to maintain the benefits of video-based training while creating a more life-like simulation. This area has not received much attention, but will allow researchers to look specifically at the information processing aspects of training decision making.

Hays and Singer (1989) use the term *fidelity* to describe how much a simulated environment is comparable to the real life task or environment. Further, Stoffregen, Bardy, Smart, and Pagulayan (2003) use the term *physical fidelity* to describe how the simulation looks compared to the real thing, and *psychological fidelity* or *experiential fidelity* is how the participant perceives the simulation and how life-like they believe it to be. More recent research (Regenbretcht & Schubert, 2006) refers to fidelity as presence, and investigated human interaction in virtual environments. This falls with a large body of research that investigates different feeling within virtual environments for training purposes (e.g., Heeter, 2006; Olmos, Bouillot, Knight, Mabire, Redel & Cooperstick, 2012). In aviation simulation research, Kolf (1973) proposed that training in faster than real time provides a more precise feeling and replicates the demands of the ‘real’ experience. This was particularly stressed for fighter pilots, where ARTT was implemented.

ARTT involves playing video faster than normal time in order to increase the required processing speed for decisions made by participants. Schneider (1985, as cited in Guckenberger et al., 1993) also gives a brief insight into expertise and automaticity as it relates to using speeded video simulations:

> Critical high performance skills that are practiced at least in part in an ART environment could lead to faster acquisition of automaticity patterns of performance, less opportunity for memory decay, and a sustained level of motivation during training. (p.5)

Given the demands of Australian football, fast paced invasions sport, where tackling and full contact is permitted within the rules, certainly adds pressure on decision mades on field. Sport, military and aviation domains require their personnel to perform skills automatically and accurately in complex and dynamic situations. They often need to make decisions and act upon partial or incomplete information or cues and usually perform under time pressure (Ward, Farrow, Harris, Williams, Eccles & Ericsson, 2008). Regardless of the comparisons drawn between the decision demands of military, aviation and sport, Ward et al. (2008) highlight the reality that there is little research collaboration between the disciplines. Ward et al. propose that if training research is to make any ‘real progress’ in developing actual performance, researchers need to focus training programs on 'the most central or crucial aspect of performance … particularly under time pressure' (p.76). This highlights the potential efficacy of adopting the ARTT paradigm to sport.

Within sport, in particular AF, Lorains and MacMahon (2009) investigated the effects of speeded video on the decision-making performance of elite, sub-elite and novice participants on a single test of performance. Two video speeds were tested: normal and 1.5 speed (1.5 times faster). Elite and sub-elite groups performed significantly more accurately on both speeds compared to novices, and the elite group performed better than the sub-elite in the fast speed condition. The improvement in elite performance with increasing video speed was attributed to the elite athletes performing more accurately when they had less time to think about the skill.

In a follow-up study to Lorains and MacMahon (2009), Lorains et al. (2013 [Chapter One of this thesis]) used the EPA to identify characteristics of elite decision-making performance, using speeded video as a process-tracing method. Lorains et al. used a video-based decision-making task, including six different video speeds, to further understand the effects of video speed on elite performance. Elite, sub-elite and novice participants watched a series of sport-specific (AF) video clips in different speeds, and made decisions for the person in possession of the ball. Similar to the findings of previous expertise research (Fitts & Posner, 1967; Beilock et al., 2002; Beilock et al., 2004), Lorains et al. found that elite athletes made more accurate decisions under faster speeds, when they were able to perform more automatically, compared to novices. The elite group's performance continued to improve as the video speed increased. The sub-elite group did not differ in accuracy scores from the elites until video speeds reached 1.5 speeds and above. The novice group scored poorly on all video speeds, as expected. This poor performance was attributed to the novices' overall lack of skill and, thus, lack of automaticity in general.

Based on participant performance, as well as previous research in aviation and military training (Guckenberger et al., 1993; Kolf, 1973), the optimal training speeds identified by Lorains et al. (2013 [Chapter One of this thesis]) were the 1.25 and 1.5 speeds. Following each decision, elite and sub-elite participants were asked to rate how ‘game-like’ each video speed felt when making a decision. Regardless of performance levels, both skill groups identified 1.25 and 1.5 video speeds as feeling most ‘game-like’ when making a decision. This is an influential finding for the use of speeded video in the design of a more representative video-based decision-making task, given that psychological fidelity can create a more life-like simulation without increasing the actual look or function of the simulated environment.

Each of these pieces of research is an important stepping-stone in the development of a higher fidelity training intervention using ARTT. The current research aims to apply the findings of a potential optimal training speed of 1.5 in a video-based decision-making task to train decision making of elite AF athletes. A five-week training intervention was implemented, including a 1.5 speed and a normal speed training group. Two and 10-week retention tests were also completed. Building on the findings of previous ARTT research (Lorains et al., 2011; Lorains & MacMahon, 2009; Lorains et al., 2013 [Chapter One of this thesis]), the following hypotheses stood; first, it was expected that the fast speed (1.5) training group would show superior performance improvements at the post-test to those trained in normal speed or those in the control group, who received no training. As Schneider (1985, as cited in Guckenberger et al., 1993) stated, ARTT can lead to faster acquisition and less opportunity for memory decay. Second, it was hypothesised that the fast speed training group would retain greater performance improvements compared to the normal speed or control groups.

In order to assess the effect the video-based training intervention had on match performance, the design also included a transfer test of decision making. Starkes and Lindley (1994) highlight that devising an appropriate transfer test for the complex task of open field sport decision making is difficult and has not been successfully implemented in previous research (e.g. Thiffault 1974; 1980). The more cognitive processing similarities there are between the training environment and the real performance, the higher the level of transfer, due to transfer-appropriate-processing (Lee, 1988). It was hypothesised that those participants trained at fast speed would show greater transfer on-field, because the information processing demands would be similar due to training in a higher fidelity simulation.

The design of this training intervention is compared to previous training studies (anticipation based) in Table 2.1 below.

Table 2.1

Comparison of taining research designs

Author	N	Intervention duration	Sessions per week	Items per session	Post test	Transfer test	Retention test 1	Retention test 2
Current Thesis Research	45	5-weeks	One	12 clips	Yes	Yes	Yes (2-weeks)	Yes (10-weeks)
Gabbett et al., (2007)	25	4-weeks	Three	30 trials	Yes	Yes	Yes (unspecified time frame)	No
Williams et al., (2002)	32	1-week	One	45mins	Yes	No	No	No

Method

Participants

Forty-five elite AF athletes were involved in the training intervention. They were randomly assigned to one of three groups. The fast speed training group included 16 players (mean age of 23.3 years and 4.2 mean years playing at AFL level). The normal speed training group included 15 players (mean age of 22.1 years and 2.2 mean years playing at AFL level).. The control group included 14 players (mean age of 22.4 years and 2.4 mean years playing at AFL level). All players were from the same AFL club (which is the highest level of competition in the sport) and the spread of positions (defence, forward, mid-field) was distributed amoung the groups. The University Ethics Committee approved all procedures, and all participants provided informed consent prior to the collection of data.

Equipment

The videos used in the AF decision-making training intervention were the same design as those used in Chapter 1, though they were difference scenarios. They were sourced from a broadcast camera view of AFL game-day footage. These included video clips from one team in possession of the ball moving into attack (inside 50 plays), kicking out from defence (kick-ins) and plays throughout the midfield. Each video clip was edited in Adobe Premiere Elements version 9.0, using the time stretch feature to increase the speed to 1.5 for the fast speed training condition.

Prior to manipulating the speed of the clips, three AFL coaches independently rated each clip by awarding three, two and one point(s) based on their opinion of the best three decisions available in each clip, as in Study 1 (Chapter 1 of this Thesis). Ratings were completed before participants were randomly assigned to groups, so they were blind to conditions. The clip difficulty was not specifically measured in the research design. The difficulty was anecdotally understood to be even across clips. Experimental psychological software testing tool E-Prime V2 Professional was used to present and collect data on individual laptops, recording and automatically scoring each response.

Procedure

Participants were randomly assigned to one of three groups: fast speed training (completed in 1.5 times normal speed), normal speed training (completed in normal speed) or control. The control group did not complete training, but completed pre-, post- and retention tests. Table 2.2 displays a timeline of the testing.

Participants were seated at an individual 17-inch screen laptop and wore headphones. They watched each video clip, which paused prior to the key action. Once paused, participants heard a beep and used the computer mouse to indicate on the screen where they would target their disposal (i.e., a handball pass or kick). Options included other players, an area of the ground, in between the goal posts, a space for the player to run on to or play-on themself (click on the player). Participants were told to make their decision as quickly as possible once they heard the first beep. After the first beep, they had three seconds to respond. Warning tones for time running down commenced at two seconds after the initial beep. During the training phase, participants saw a feedback screen (a screen shot of the final frame outlining the AFL coach ratings of the three, two and one point options) following every third clip. Feedback was only available after every third video clip (reduced delayed feedback model) to minimise a reliance on the feedback during training (Vickers, Livingston, Umeris-Bohnert & Holden, 1999).

Decision accuracy was the performance measure used. This was based on AFL coach ratings, as detailed above. Any responses outside of these ratings received zero points. Similarly, if a player was unable to make a decision due to the time pressure (three seconds), a score of zero was awarded. The training intervention timeline is outlined in Table 2.1.

Pre-test. Participants saw two warm-up clips then 12 video clips in normal speed and used the computer mouse to indicate on the screen where they would target their disposal. These clips were not used in training sessions. Each session was for approximately 8 minutes in duration.

Training intervention. Procedure was the same as pre-test. During the training phase, participants saw a feedback screen (a screen shot of the final frame outlining the AFL coach ratings of the three, two and one point options) following every third clip.

Post-test. The procedure was the same as the pre-test (with new video clips not previously seen by any of the players).

Retention tests. The procedure was the same as the pre- and post-tests, with new video clips.

Transfer tests. Game-day matches for a sub-group of participants from each of the three groups were analysed. The two weeks prior to the video-based pre-test were chosen, the week of and the week following the post-test, the first retention test and the final retention test. Decisions of 13 players, who played in all matches, were analysed (six fast speed, four normal speed and three control). Four of these players (two fast speed, one normal speed and one control) were also selected for analysis of their performance for retention tests one and two. Decision accuracy was measured using coach ratings and the team game plan (three, two and one point[s]), identical to the measurement used in the video-based training.

Table 2.2

Timeline of Training Intervention

	Group		
Week	Fast (n = 16)	Normal (n = 15)	Control (n = 14)
1	Pre-Test Training 1	Pre-Test Training 1	Pre-Test
2	Training 2	Training 2	No Training
3	Training 3	Training 3	No Training
4	Training 4	Training 4	No Training
5	Training 5	Training 5	No Training
6	Post-Test	Post-Test	Post-Test
7–8	No Training	No Training	No Training
9	Retention Test	Retention Test	Retention Test
10–18	No Training	No Training	No Training
19	Retention Test	Retention Test	Retention Test

Two people, trained by coaches in the specific game plan, coded each match. For a more in-depth method of the coding system used, see Lorains et al. (2012). The kappa statistic was used to assess the reliability of the two coders (< 0 = less than chance agreement, 0.01–0.20 = slight agreement, 0.21–0.40 = fair agreement, 0.41–0.60 = moderate agreement, 0.61–0.80 = substantial agreement and 0.81–0.99 = almost perfect agreement, Landis & Koch, 1977). Two coders analysed five players to assess inter-rater reliability for accuracy ($k = .84$). Random samples of these matches were coded a second time by both coders to assess intra-rater reliability. Results showed almost perfect agreement for both coders for decision accuracy (k = .91, k = .92). Each kappa statistic result also showed a significant p value of less than .001.

Data Analysis

To analyse decision accuracy results, single one-way between-within group ANOVA design was used. The independent variable was decision accuracy. The dependant variables included, group (fast, normal, control), and test time (pre, training, post, retention). Follow up pairwise comparisons were used to explore significant main effects. A three group (fast, normal and control) x four test time (pre-, post-, retention one and retention two) repeated measures ANOVA was used for the transfer testing. Bonferroni adjustment was applied to all analyses to control for type I error, and effect sizes were calculated using Cohens d.

Results

Video-Based Training

A one-way between groups ANOVA found no significant differences for accuracy between fast speed, normal speed and control groups at the pre-test, F (2, 41) = .040, p = .961, see Figure 2.1.

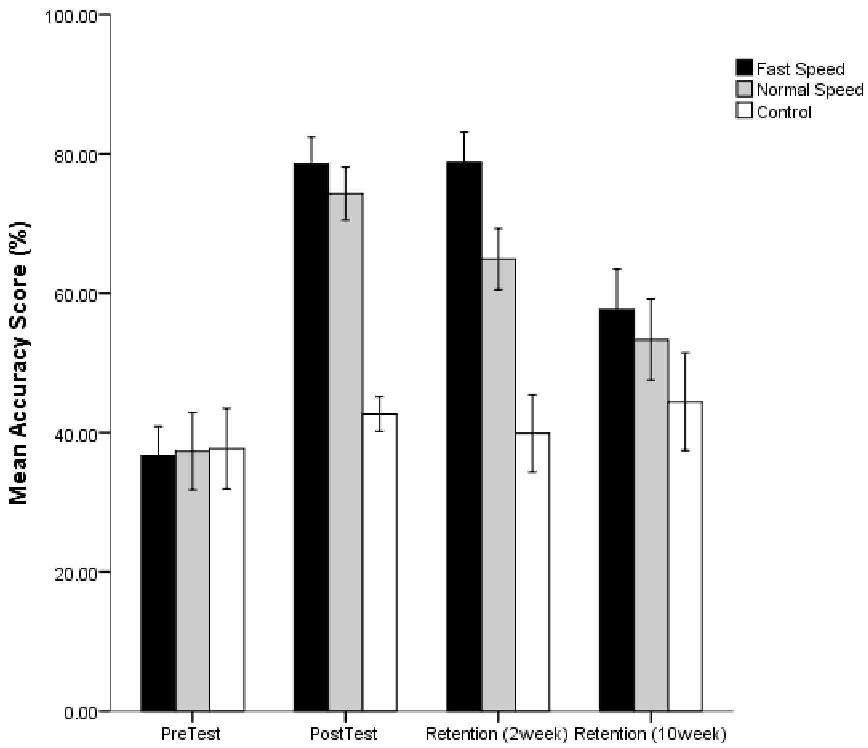


Figure 2.1*: Mean accuracy scores by all groups.*

A one-way between groups ANOVA was used to investigate differences between fast speed video and normal speed video for accuracy between training groups. No significant differences were found at the first training session, *F* (1, 28) = 2.008, *p* = 1.68, d = .52. The fast speed training group showed higher accuracy over the normal speed training group from the second training session, *F* (1, 28) = 5.276, *p* = .029, d = .84. This significant trend continued for the third training session, *F* (1, 28) = 12.28, *p* = .002, d = 1.28, fourth training session, *F* (1, 28) = 10.154, *p* = .004, d = 1.17 and the fifth and final training session, *F* (1, 28) = 12.544, *p* = .001, d = 1.30, see Figure 2.2. Cohen's d returned large effect sizes. Additionally, pairwise comparisons revealed significant linear improvements for both fast and normal speed groups, between training sessions one and two, *p* = .008, three and four, *p* < .001 and four and five, *p* < .001.

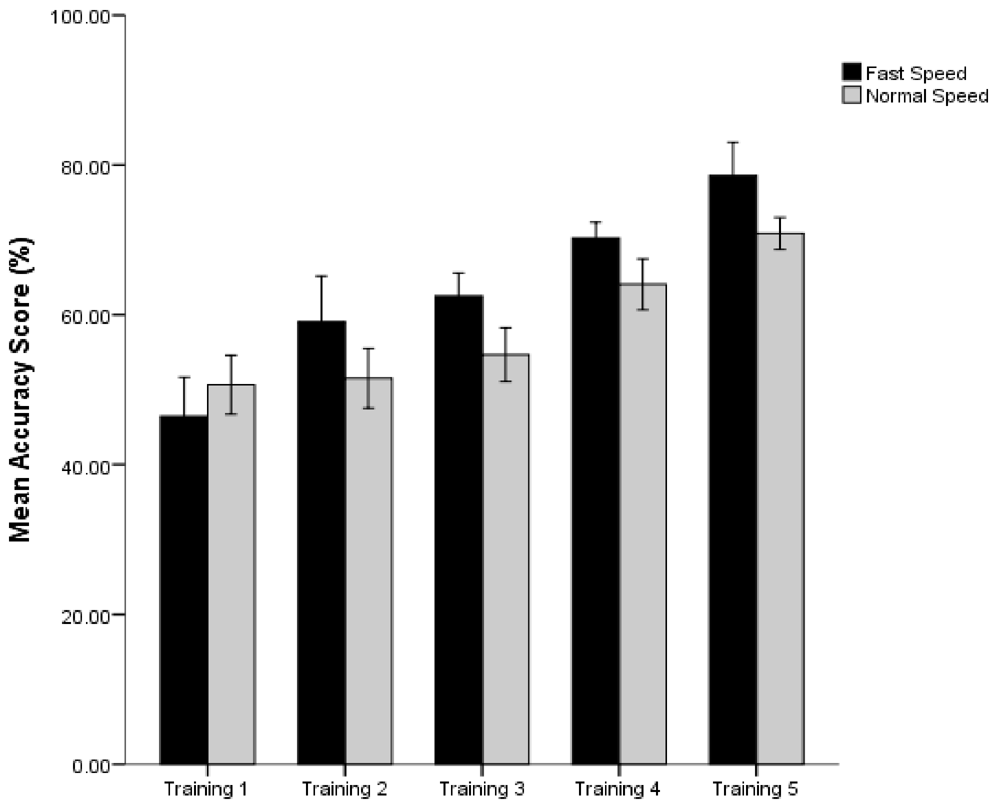


Figure 2.2: *Mean accuracy scores by video trained groups.*

A one-way between group ANOVA indicated significant differences for accuracy scores on the post-test, *F* (2, 41) = 141.73, *p* < .001, two-week retention test, *F* (2, 41) = 75.42, *p* < .001 and the 10-week retention test, *F* (2, 38) = 5.32, *p* = .009. Post-hoc testing revealed that at the post-test, the fast speed training group were no more accurate than the normal speed group, *p* = .158, d = .62, but were more accurate than the control group, *p* < .001, d = 6.4. The normal speed training group were also more accurate than the control group at this point, *p* < .001, d = 5.28.

At the two-week retention test, the fast speed training group was more accurate than the normal speed training group, *p* < .001, d = 1.74, and the control group, *p* <. 001, d = 4.49, with an extremely high effect size. The normal speed training group was also more accurate than the control group, *p* < .001, d = 2.82. Results from the 10-week retention test revealed no significant differences between the fast speed and normal speed training groups, *p* = .527, d = .43, or between the normal speed training and the control groups, *p* = .81, d = .81. The significant difference was between the fast speed training and the control groups, $p = .008$, d = 1.25.

On-Field Transfer Tests

A three group (fast, normal and control) x two time (pre- and post-test) repeated measures ANOVA was completed to investigate any significant differences between video training groups on transfer tests of decision accuracy on-field. Results revealed no significant interaction effects and no main effect of group. All three groups increased in decision accuracy with a main effect of test time shown, Wilks Lambda = .219, F (1, 10) = 35.76, $p <$ .001. The partial eta squared value of .781 for this effect reflects a large effect size. Further analysis into quality of decision, as shown in Table 2.3 in the form of percentage of frequencies, shows that following the training intervention, the fast speed training group chose the best option (three points) more often compared to the normal and control groups, while the two, one and zero points decreased. This trend continued throughout both retention testing, but was not as prevalent in the second retention test.

The four participants analysed for retention tests in addition to pre- and post-test scores were included in a three group (fast, normal and control) x four test time (pre-, post-, retention one and retention two) repeated measures ANOVA. Due to the extremely small sample size, no significant differences were found in any of the data. Power analysis calculations recommended an additional 17 participants in order to reach significance levels.

Table 2.3

Percentage Frequency of Decision accuracy Scores Across Group for Transfer Test (%)

	Pre-Test				Post-Test				Retention 1				Retention 2			
Decision accuracy	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3

Fast	20	13	23	44	2	4	28	66	20	5	18	58	30	13	17	39
Normal	23	20	26	31	6	11	22	60	23	0	23	54	25	13	25	38
Control	21	12	24	42	13	10	16	62	25	0	13	63	43	0	14	43

Note: 3 points = best option, 2 points = second best option, 1 point = third best option, 0 points = poor decision or loss of possession

Discussion

The aim of this research was to test the effectiveness of a video-based decision-making training intervention. The training intervention trained elite AF athletes on either ART video or normal speed video over five weeks, and compared these results to a control group who received no training. The pre-test showed no differences in decision accuracy between groups. As hypothesised, the ART group showed greater overall improvement during training compared to the normal speed training group, with superior performance from training session two to session five, inclusive. While the normal speed training group also improved performance, the athletes trained in ART increased decision accuracy earlier in the training intervention than the group trained with normal speed video. As suggested by Schneider (1985, as cited in Guckenberger et al., 1993), the results imply that those trained at least in part in ART will have faster acquisition. Further, following the two-week retention test, those participants trained in ART maintained their performance improvements longer than other groups, before memory decay occurred in the proceeding eight weeks. The sustained performance improvements of those trained at ART supports previous research (Guckenberger et al., 1993; Lorains et al., 2013 [Chapter One of this thesis]) that 1.5 could be an optimal video training speed because it increases the fidelity of the simulated environment.

This training intervention builds upon previous decision-making research (Lorains & MacMahon, 2009; Lorains et al., 2013 [Chapter One of this thesis]) and is a positive development in the use of video-based training to improve decision making. The benefits of more traditional video-based training are well documented (Starkes & Lindley, 1994), but have often been criticised compared to perception-action coupled training, due to the lack of fidelity and low representativeness of the task (Araujo et al., 2006). Using ARTT creates a cost and resource effective higher fidelity simulation, as reported by pilots and athletes, who rate fast speed video more indicative of real life performance compared to that of normal speed (Guckenberger et al., 1993; Kolf, 1973; Lorains et al., 2013 [Chapter One of this thesis]). Moreover, using ARTT to create higher fidelity simulations allows coaches and researchers to maintain the benefits of video-based training (e.g., little set up, not physically taxing and inclusive of injured players). The use of ARTT also allows coaches and researchers to focus and separate the skill execution from the cognitive processes of decision making for training purposes.

Decision-making accuracy was increased significantly by training in ART simulations in the computer-based task compared to normal speed training throughout training. At the post-test, however, performance improvements were matched by the normal speed group. As stated by Kolf (1973), those trained at least partly in ARTT will show faster acquisition and longer retention. This was the case in this research, the ARTT group, while matched at the post test stage by the normal speed group, retained the performance improvements, as shown in the first retention test. It is important to note that the control did improve despite no training. This was attributed to on field training that was completed throughout the season. By no means, does this research advocate the sole use of video-based training for decision-making, rather that it should be used in conjunction with other training. It simply provides a reliable method to expose athletes to a wide variety of scenarios or simulations without physical fatigue.

It is, however, an important aspect of any training to be able to measure transfer of performance improvements onto the field (Starkes & Lindley, 1994). The use of a specifically designed performance analysis notational analysis system for decision making is a major highlight of this research. Starkes and Lindley (1994) state that future research should design an easy to administer transfer test to allow measurement of the same components that are involved in training. Measures such as these are lacking from previous decision-making research.

This transfer assessment tool is one of the first to assess in-game decision-making quality, where the skill execution and cognitive components of decision making are separated (see Lorains et al., 2012 for further detail on the protocol). As the coded games were taken at the beginning and end points in a season, it was expected that there would be improvements in decision accuracy in all groups, due to on-field training and match play. The sensitive nature of the coding system may not have been enough to differentiate between skill groups. Decision accuracy was measured on the three-point scale (three points = best option, two points = second best option, one point = third best option, zero points = poor decision or loss of possession). The interesting outcome of the transfer tests is that overall each group improved their decision making following the training intervention and tended to choose the best option (awarded three points) more often than they chose the two point option or below. This trend was most noticeable in the fast speed group compared to others. While the results from the transfer test did not show statistically significant differences between video-based training and on-field performance, due to small sample sizes, the trends from the decision accuracy offer a baseline for future research to build upon.

A challenge to any transfer tests and live game analysis are the logistics of athlete injury and team selection issues, which usually results in a small sample of players being available in all games for analysis. The trade-off for a small sample size and the accompanying logistical issues, as found in this current research, is that the analysis of transfer was undertaken in live game situations. This allowed for a true reflection of performance, something that staged scenarios or mock games cannot provide (Thiffault, 1974; 1980).

The application of ARTT for decision making in sport, enhanced by the development and inclusion of a decision-making-specific testing notational analysis system for in-game analysis, can improve and monitor decision-making skills. As highlighted by Lorains et al. (2011), speed manipulations can be used as a method to create a more ‘game-like’ training scenario. This training method is relatively simple and could be easily implemented into training programs, while maintaining the benefits of video-based training, making it practical and accessible for sporting clubs to use. In summary, video-based decision-making training improves decision accuracy; training in ART, however, will produce faster acquisition and a higher retention rate of performance improvements.

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Chapter 3: Performance Analysis for Decision Making in Team Sports

(From: Lorains, M., Ball, K. & MacMahon, C. (2013). Performance analysis for decision making in team sports. *International Journal of Performance Analysis in Sport.*)

Notational analysis in sport allows coaches and sport scientists to record performance indicators such as movement, skill execution and tactical measures (Hughes & Franks, 2004). Selected performance indicators can be used to assess individual, team or an opponent's performance (Hughes & Bartlett, 2002). James (2006) suggested that the future of notational analysis systems should incorporate all facets of performance, and most importantly, how they affect each other.

Accurate decision making in sport has been identified as a significant factor in successful elite performance (Baker et al., 2003). Baker et al. (2003) describe this as being the case particularly for fast-paced team invasion sports. Expert decision makers within sport use advanced cues, a larger knowledge base and superior anticipation in order to make faster and more accurate decisions than their lesser-skilled counterparts (Baker et al., 2003; Lorains et al., 2013 [Chapter Two of this thesis]).

A large portion of the research on decision-making performance, however, focuses on staged scenarios or video-based decision-making tasks (Starkes & Lindley, 1994; Lorains & MacMahon, 2009) to assess decision accuracy. Despite the importance of decision-making skill in overall performance, there are very few notational analysis methods to assess this ability in real match situations. Hughes and Franks (2004) highlight how performance analysis can help to inform coaches and athletes in a variety of performance measures; the cognitive components of decision making are not included as a performance measure. A majority of reasearch simply uses notational analysis to analyse movement performance and physical skill execution only (e.g., McGarry & Franks, 2003; Hughes & Franks, 2004; Thomson, Lamb & Nicholas, 2006). Despite the abundance of research that states the integral role decision-making plays (Araujo et al., 2006; Baker et al., 2003; Starkes & Lindley, 1994), no reliable method of performance analysis has been developed, aside from testing in video-based simulations.

Using video to simulate decision-making scenarios has many practical benefits. When testing, it allows injured athletes to be involved when they cannot participate in physical training, it is low cost and easy to set up, coaches and other teams do not need to be present and it can be individualised for the needs of the athlete (Lorains, MacMahon, Ball & Mahoney, 2011; Starkes & Lindley, 1994). Video simulations can also be used as a training tool for decision making.

Video-based testing and training does not, however, give information regarding performance levels or improvements in on-field or in real game situations. In order to gain true insight into performance, analysis should be carried out on real games or simulations as close as possible to real games (Araujo et al., 2006). Methods such as notational analysis can be used to do this, either from live matches or using post-match video.

One of the first attempts, outside of traditional sport performance analysis was completed by Oslin, Mitchell and Griffin (1998) within the physical education domain. Oslin et al., (1998) developed the General Performance Assessment Instrument (GPAI). The assessment tool used game components and individual components including physical and tactical performance measures. The methods shown could be useful in a range of sport, yet it was not tested on elite sport in game situations, only on junior school aged children participating in small sided games. Specific to elite sport, Bruce et al. (2009) were one of the first and only to use notational analysis to assess decision making in game situations. They assessed defensive pressure, decision-making complexity, pass outcome, error type and error direction of elite and sub-elite level netball players. Results revealed that defensive pressure and decision-making complexity had a smaller influence on the elite netball players' performance than it did on the sub-elite players.

Bruce et al. (2009) used the outcome of the pass as the measure of accuracy in netball decision making, with the aim of measuring transfer on-field. A major limitation of this method was the linking of skill execution with the cognitive components of decision-making performance. The next evolution of this type of analysis requires a separation of decision and execution errors. Without this separation, assessment of decision making becomes clouded. For example, a player may make an accurate decision or action choice, yet not execute the skill effectively, meaning the outcome is unsuccessful. The use of methods that identify if errors are technical or decision-making based is needed to increase the effectiveness of assessing decision-making performance. This is especially the case for sports where execution difficulty is higher due to features such as a larger playing area, high collision and contact frequency and an oval ball, which creates less predictable movements.

The current research aimed to develop a notational analysis method that evaluates decision-making performance in a fast-paced team sport. This was a part of a larger training intervention (Lorains et al., 2013 [Chapter Two of this thesis]) of a video-based decision-making task. The coding system was developed and tested to measure the level of transfer from video-based training to on-field performance. Four matches throughout the season were used, in an attempt to gain a more accurate assessment of individual performance. The main considerations were game context (round, time in the match, score line, position on field and motion of the player with the ball), decision making (quality, number of options and pressure) and execution (disposal type, effectiveness and error direction). These parameters were chosen as they reflect the demands of the game, both cognitive and physical. It was hypothesised that those who completed the video based training would show the performance improvements gained on-field, compared to those that did not complete the training (control group). The sensitive design of the notational analysis system is expected to highlight these differences.

Method

Participants

Thirteen male elite athletes who were currently competing in the same team within the AFL were involved in the analysis. They were in two groups, as determined by whether or not the completed the video-based training intervention (Chapter 2 of this thesis). The video training group contained 9 athletes and the control group contained 4 athletes. The participants had a mean age of 23.4 years (SD = 1.8) and mean playing years at AFL level was 4.1 years (SD = 2.3). Informed consent was provided by all participants prior to assessment; they were unaware of which matches were being coded.

Procedure

Decision-making coding system. A decision-making coding method was developed in consultation with three AFL level coaches from the same team. Environmental and outcome parameters that were considered important and influential to a player when they had the ball were refined based on the demands of elite level AF athletes and are outlined in Table 3.1.

Under the decision-making category, decision accuracy was measured on a zero-to-three-point scale. This scoring scale was identical to that used in the decision-making task, being determined by three AFL coaches measuring decisions for each clip. Also in this category were the number of options and defensive pressure applied to the ball carrier. These factors were identified by coaches as having the biggest effect on an athlete's decision-making process. These were particularly important in evaluating any changes in decision making between games, because the nature of games can be different (Wisbey, Montgomery, Pyne &

Rattray, 2010). Match context included the time of game (by quarter) to indicate if decision effectiveness changed during the course of a game, perhaps due to fatigue throughout the match or adjusting to the opposition. The position on the field and the speed of the player disposing of the ball were also included in this category, because these alter the decisions available. Finally, execution was evaluated, examining the type of disposal produced, and in the case of an error or ineffective pass, the direction in which this error occurred. There was also a detailed outcome scoring system that provided considerably more depth than a ‘hit and miss’.

Table 3.1

Parameters and Codes for Notational Analysis Method

	Parameter	Code
Match context	Time in match (quarter)	1 2 3 4
	Position on field	4 = Defensive 50 3 = Forward 50 2 = Mid field 1 = Wing
	Motion	4 = Stationary 3 = Slow Jog 2 = Run 1 = Sprint
Decision making	Quality	3 = Best 2 = 2nd best 1 = 3rd Best 0 = Poor decision
	Number of options	1 2 3 4+
	Defensive pressure	4 = Currently tackled 3 = Close to tackle 2 = Opposition <5m – influence 1 = Opposition <5m – no influence 0 = Opposition >5 m
Execution	Disposal type	4 = Long kick >20m 3 = Short kick <20m 2 = Long handball >10m 1 = Short handball <10m
	Effectiveness	10 = Goal Effective pass; 9 = Received and played on 8 = Received but slowed play 7 = Dropped (retained possession) 6 = Put into free space Ineffective pass; 5 = Put into free space (lost possession) 4 = Dropped (lost possession) 3 = To marked player 2 = To opposition 1 = Missed Target
	Error direction	6 = High 5 = Low 4 = Left 3 = Right 2 = Short 1 = Long

Analysis was carried out on video footage of four matches from one season, two early season and two later season. These matches were chosen as to be able to provide comparative data throughout the season. These matches also fell in line with the schedule of the pre and post tests for the video-based training intervention. Match film was sourced from broadcast footage available from the AFL. This footage included both side-on and back-on (‘behind the goals’) footage. Each time the player received the ball and consciously disposed of it (i.e., looked at options and made a decision) their performance was coded within each of these parameters. Where the player did not have time to assess the options (for example, they were tackled as soon as they received the ball) the disposal was not considered for assessment. This coding was completed using a specifically designed Microsoft Excel spread sheet (see Figure 3.1).

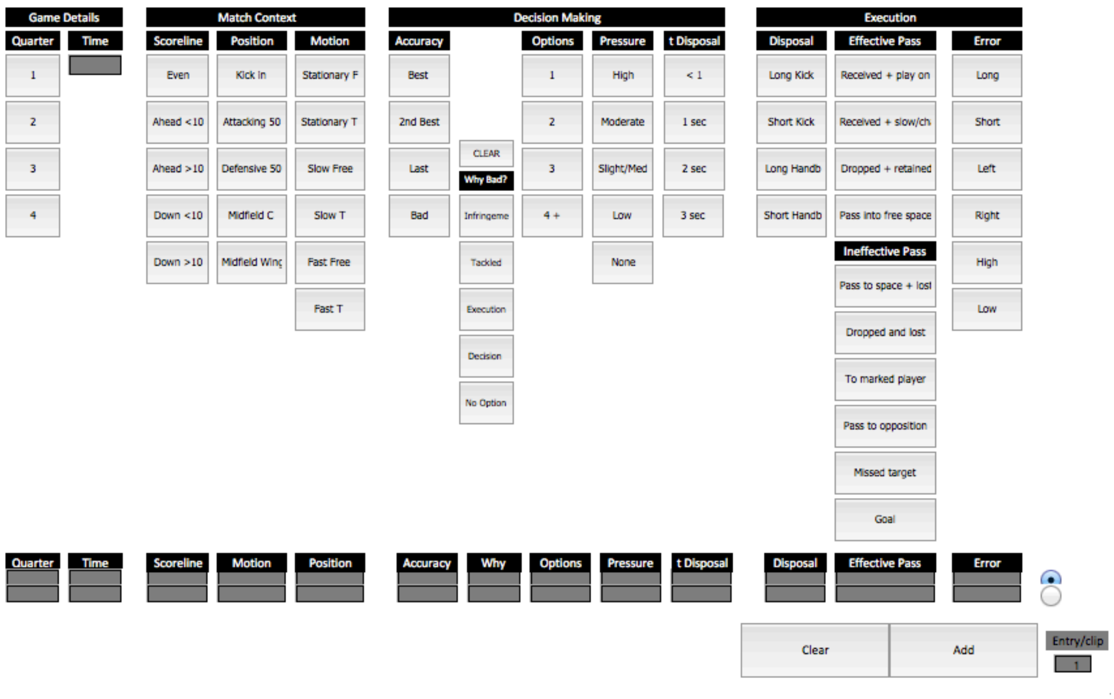

Figure 3.1: *Screen shot of coding interface used for notational analysis.*

Two coders were involved in the coding process and both participated in a thorough training program prior to coding. The program involved being trained by AFL coaches in the specific team rules and game plan for each match, as well as in basic decision making in AFL. Training continued with an experienced performance analyst in fine-tuning coding of more complex factors, such as defensive pressure and execution effectiveness. Finally, both coaches and coders analysed a sample of decisions and the results were compared to ensure coders were producing coach-expected results.

Decision-making task. Participants completed a five-week video-based decision-making training intervention. This included a pre-test, five training sessions, post-test and retention testing at two and 10 weeks. In each session, participants were seated at individual 17-inch screen laptops. They watched a series of attacking AFL video clips, which paused prior to the key action. Participants then used the computer mouse to click on the screen the location where they would pass the ball (i.e., a handball pass or kick). Options could include other players, an area of the ground, in between the goal posts, a space for the player to run on to or to retain possession. They were encouraged to make their decision as quickly as they could and within three seconds following the pause screen. Decision accuracy was the performance measure used. This was based on AFL coach ratings and involved three points for the best response, two points for the second best response, one point for the third best response and zero points for any responses outside of these or if they were timed out. The intervention was part of a larger study examining decision-making interventions.

Results

Data Analysis

Reliability was was measured based on the kappa statistic and agreement values of Landis and Koch (1977). Parametric statistics for the in-game analysis included a series of one-way ANOVAs. Repeated measures design was used for the video-based decision making task and the transfer tests. Independent variables included group (video training, control) and test time (early season, late season). The dependant variables included decision accuracy, defensive pressure, skill execution. Pearsons correlation was used to investigate corrleations between performance indicators from the notational analysis system.

Reliability

Two coders were assessed for reliability using the kappa statistic and agreement values of Landis and Koch (1977). These were: < 0: less than chance agreement; 0.01–0.20: slight agreement; 0.21–0.40: fair agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement and 0.81–0.99: almost perfect agreement.

All 13 players (100% of the data) were analysed by both coders to assess inter-rater reliability for decision accuracy (k = .84), defensive pressure (k = .90), the number of options (k = .79), the time in match (k = .98), the position on-field (k = .97), the motion of the player (k = .92), disposal type (k = .88), effectiveness (k = .83) and error direction (k = .80). Random samples of these matches were coded a second time (three weeks later) by both coders to assess intra-rater reliability. Results showed an almost perfect agreement from coder one for accuracy (k = .91), defensive pressure (k = .94) and number of options (k = .91) and from coder two for accuracy (k = .92), defensive pressure (k = .93) and number of options (k = .93).

In-Game Analysis

Video training and control groups were collapsed for this analysis to increase group size, and to increase power of the studies results. A one-way ANOVA revealed a significant interaction effect between total accuracy and season time, F (3, 22) = 8.76, p = .001, partial eta squared = .544. Further analysis into the quality of decisions showed that later in the season, players were choosing the best option more often than other options. This is displayed in Table 3.2 in the frequencies of decision.

No significant effects were found between pressure and season time, F (4, 21) = 1.45, p < .05, partial eta squared = .179. Season time and number of options available also yielded non-significant results F (2, 23) = 1.15, p = < .05, partial eta squared = .091.

A one-way ANOVA for effectiveness of skill execution revealed that the athletes disposed of the ball to free space and still retained possession better later in the season, F (1, 24) = 5.003, p = .34, partial eta squared = 0.172. Disposals to teammates that dropped the ball decreased throughout the season, F (1, 24) = 9.74, p = .005, partial eta squared = .289. No other significant differences in skill execution were apparent.

Table 3.2

Frequency of Decision accuracy from Early to Late Season (%)

	Decision accuracy			
	0 points	1 point	2 points	3 points
Early Season (Rounds 1 & 2)	21	15	24	39
Late Season (Rounds 10 & 11)	8	8	19	64

Correlations (using Pearson correlation coefficient) between decision accuracy and effectiveness of skill execution early in the season showed a strong positive correlation between effective execution and poor decisions r = .661, n = 13, p = .014. Later in the season, this trend continued: a negative correlation between effective and ineffective disposals r = 1.00, n = 13, p < .001 and a strong positive correlation between effective execution and poor decisions r = .727, n = 13, p = .005.

Video-Based Decision-Making Training Intervention

A two group (video training and control) x two test time (early season and late season) mixed ANOVA with repeated measures was performed to investigate any performance improvements following the video-based training intervention. Results revealed no significant differences in total decision accuracy F (1, 11) = .028, p = .87, partial eta squared = .003, a very small effect size. For full results of the larger video-based training intervention, please see Lorains et al. (2013 [Chapter Two of this thesis]). The results here are only related to those 13 players that were analysed on-field.

Transfer from Video-Based to On-Field

A two group (video training and control) x two test time (early season and late season) repeated measures ANOVA revealed no significant interaction effects or main effect of group. Both groups increased in decision accuracy with a main effect of test time shown, Wilks Lambda = .219, F (1, 10) = 35.76, $p < .001$. The partial eta squared = .781 for this effect.

Discussion

A range of factors inherent in the on-field performance context can influence decision making. This research used a specifically developed notational analysis system for decision making that incorporates these factors. Previous studies that have analysed decision making in live game situations (Bruce et al., 2009) have neglected to measure the subcomponents of decision accuracy, instead using outcome of the skill execution alone. The current research analysed the decisions of 13 players over four matches, specifically looking at decision accuracy and the influencing factors.

The first aim of this study was to develop a reliable decision-making-specific notational analysis system that separated the physical execution components from the cognitive components involved in decision making in Australian football. A highpoint of this research is the consistent achievement of very high reliability ratings for each performance indicator. A number of options are a difficult performance indicator to code as there may be a number of players on the ground, but all options may not be consistent with the team game plan. Despite these difficulties, a near perfect inter-rater reliability was achieved, which shows the robustness of this notational analysis system, as well as the importance of providing high level training to coders.

The results produced from this notational analysis system provide support for the need to separate the cognitive and execution aspects of decision making. The analysis of correlations was completed to highlight the coaches that the two aspects of skill cannot go hand in hand. They are two important aspects that, of course, a intertwined but where possible should be able to be measured seperately. This will allow coaches to more accurate identify performance areas to be trained. It is important to note that, while this research does highlight the need for seperation of the two elements, in a game situation, the two are intertwined. The main reason for speration is for the identification of training needs of an athlete.

Bruce et al. (2009) based a good decision on a good pass. The use of this notational analysis system emphasises that decision making cannot be measured purely on the outcome of the physical execution. The delineation of decision and execution is vital in gaining a true indication of decision-making performance. The sensitive nature of the decision accuracy ratings also allowed insight into the quality of decisions being made throughout the season. Identifying that athletes were choosing the best option more often later in the season is important at the practical level for coaches to see improvement. Without this level of detail in the decision accuracy component, a vastly different picture is provided to coaches. A simple ‘good’ or ‘bad’ decision rating in early matches saw athletes make good decisions 78% of the time compared to poor decisions 21% of the time, leading to conclusions that they were already quality decision makers. However, the more sensitive scoring system used in this study enabled decisions to be rated between best to poor, which created a more accurate comparison and highlighted the areas for improvement.

Any performance analysis tool needs to be easy to administer and provide coaches and athletes with the information they require in a timely manner. Anecdotal evidence from the coaches, athletes and performance analysts were that the process used in this research was easy to implement and use in order to analyse performance. Also, it covered all necessary aspects of performance. Coaches were satisfied with the high level of reliability between and within the coders. The main highlight for coaches was that it collected both aspects of decision making, cognitive and skill execution, but allowed the two to be analysed independently of each other.

The second aim was to use this specifically designed notational analysis system to assess the amount of transfer of performance improvements from a video-based decision-making training intervention. While no significant transfer effects were present, it is may be considered that this system separating the physical execution and cognitive aspects of decision making is sound in its design and provides a solid platform to assess live game performance, as well as transfer of skills. This statement is supported by Hughes and Franks (2004), reporting that notational analysis is used to record and monitor athlete performance. In addition, notational analysis can be utilised as a method to assess transfer of performance gains from training interventions. Determining whether a training programme has had an effect on behaviour is a critical step that can drive decisions on the usefulness or future adoption of such programs and the expenditure of resources.

While it is important to perform this type of work and perform it in game situations, there are numerous difficulties that exist. The balance for assessing decision making in this study was a trade-off between coding enough games to gain a representative decision-making score for the team and individuals, while limiting it to a short time frame for testing to avoid contamination by learning effects during the test period. The two game window was considered reasonable in this study because it produced on average between 20 and 25 decisions per player, and these were made in conditions that did not differ significantly as indicated by other measures (e.g., game context and pressure).

This leads to a second potential limitation, being the different nature of games, which might affect overall decision making and cloud assessment. This was eliminated as an issue for this study because coding included key factors such as pressure, number of options and speed of approach to determine if the environment was significantly different, which for this study it was not. Future work needs to include these factors to ensure the data is appropriately measured and that it is not the environment generating the differences or changes in performance.

Finally, the sample of 13 players used was reduced from 24 in pre-testing due to injury and selection of the team. This is a difficulty with all in-game assessments where examination of individual player data is concerned. Short of choosing a more stable team to conduct testing on, this limitation will always exist to some degree when analysing elite team or athlete performance. With much notational analysis research, especially those carried out in live situations, a small sample size can influence results. The nature of sport means that sample size can be influenced by injury or team and player selection. For example, basing results on only one game where a key player might be out injured may not reflect the team's true performance. Similarly, one match may not reflect the true ability of an individual. This is a consideration for all notational analysis research.

Conclusion

A notational analysis system was designed to measure decision making in live match situations of Australian football. Its features included the ability to separately analyse the cognitive and physical execution components of decision making, a feature that has not been addressed in previous research. High reliability and coder agreement existed on all performance indicators. Using this system, it was found that the cognitive components of decision making specifically improved through the season. This notational analysis system also assessed transfer of skills following a video-based decision-making training intervention, showing trends in transfer onto the field. Anecdotally, coaches and players were satisfied with the processes involved and outcomes produced.

While this particular tool is specific to Austrlaian football performance indicators and skills, The design structure was developed in order to aid in simple adaptation to other sports, in particular team invasions sports (e.g., basketball, netball, soccer). The decision making components remain the same, yet the execution compnents need to be altered to cater for the given sport. Coaches agree that this analysis system is practical and easy to implement in an analysis program, with the major benefit being the separation of the cognitive and execution aspects of decision making.

Chapter 4: The Effect of an Above Real Time Decision-Making Intervention on Visual Search Behaviour

(From: Lorains, M., Panchuk, D., Ball, K. & MacMahon, C., (submitted). The effect of an ART decision-making intervention on visual search behaviour. *Frontiers in Movement Science and Sport Psychology*.)

Decision making has been described as a defining skill that distinguishes expert and novice performance (Abernethy et al., 2005; Baker et al., 2003). Research supports this notion with findings of superior decision-making accuracy by expert performers (e.g., Johnson & Raab, 2003; Lorains & MacMahon, 2009; Lorains et al., 2013 [Chapter One of this thesis]; Starkes & Lindley, 1994). The next step in gaining a more in-depth understanding of expertise is to use process-tracing methods, a step Williams and Ericsson (2005) state is often overlooked. Process-tracing methods, such as temporal and spatial occlusion techniques, point light displays, verbal reports, biomechanical profiling and visual search, allow researchers and sport scientists to not only identify differences, but to understand why those differences are apparent.

Lorains et al. (2013 [Chapter One of this thesis]) investigated the use of speeded video as a process-tracing method for decision-making expertise. Speeded video was chosen based on previous research in military and aviation training (Guckenberger et al., 1993; Kolf, 1973). It is thought to create a more life-like environment for training. Pilots reported that the feeling of training in faster video speeds (1.5x normal speed) was more reflective of flying in real life (Kolf, 1973). These findings provided a strong basis for the choice of speeded video, but also highlighted the need to investigate further.

In sport, elite, sub-elite and novice AF participants completed a video-based decision-making task in various video speeds (Lorains et al., 2013 [Chapter One of this thesis]). Results revealed that elite participants' decision-making accuracy increased as the video speeds increased, unlike the sub-elite and novice participants, who decreased in performance. Moreover, both elite and sub-elite athletes identified the speed of 1.5 as feeling most ‘game-like’ when making decisions. Lorains et al. (2013 [Chapter Two of this thesis]) also completed a speeded video decision-making training intervention, including measurement of visual search behaviours on a subset of athletes whose data is presented in this chapter.

Advances in eye movement registration systems such as the Mobile Eye (ASL, Bedford, MA) have allowed researchers to investigate the visual search patterns and strategies of athletes during physical skills and cognitive tasks such as decision making (e.g., Dicks et al., 2010; Roca et al., 2011; Vaeyens et al., 2007). Vaeyens et al. (2007) also agree that while progress in technology and understanding the mechanisms of expert decision making has advanced, more work is needed to fully understand these mechanisms of expert decision making. Henderson (2011) describes that the use of eye movement recording provides an insight into the real-world visual processes that underlie cognition and that by employing these methods, researchers are provided with a real time snapshot of visual behaviour and cognitive processing (Raynor, 1998).

Vaeyens and colleagues (2007) tested elite, sub-elite and regional level soccer players’ ability to physically respond to soccer-specific filmed scenarios and assessed their decision-making accuracy and decision-making time. Visual search strategies were also recorded and included search rate (the number of fixations per second and average duration of fixations) and fixation location (time spent fixating on various areas of the field, e.g., offensive player, ball and defender). Results revealed that the more successful decision makers spent more time fixating on the player with the ball, alternating more between that and other areas of the field. Helsen and Starkes (1999) also used a video-based visual search task with eye movement recordings. Semi-professional and novice soccer players completed a perception-action coupled decision-making task where they were required to watch a lifesized projected video and physically respond with their decision to pass or dribble. The visual search results revealed that experts used significantly fewer fixations prior to making a decision. These findings are supported by additional research in soccer investigating visual search behaviours using similar methods (Helsen & Pauwels, 1992; Savelsbergh, Williams, Van Der Kamp & Ward, 2002).

In addition to these perception-action linked designs, when visual search strategies are collected in laboratory-based environments, where the response mode requires participants to indicate their decision via mouse-click or verbal response, similar results are yielded. Similarly to perception-action coupled experiments, results from studies using this method found evidence that elite athletes make more accurate decisions while using fewer fixations of longer duration (North, Williams, Hodges, Ward & Ericsson, 2009; Vaeyens et al., 2007; Williams, Davids, Burwitz & Williams, 1994).

A series of fixations and saccades are the visual search behaviours that provide insight into the underlying cognitive process that occurs when an athlete is performing a decision-making task (Phillips & Edelman, 2008). Fixations are defined as a gaze that remains still on an object or location for more than 99.99 milliseconds (McPherson & Vickers, 2004). A saccade is defined as a gaze that moves from one location to another in less than 66.66 milliseconds and links fixations. The duration and location of a fixation may determine what information is acquired during a single fixation, and the speed at which it is obtained. In sport in particular, the investigation of eye movement patterns has revealed that elite athletes characteristically have fewer fixations on important elements of the stimulus that are longer in duration than their lesser-skilled counterparts (Raab & Johnson, 2007). The longer the fixation is on the stimulus, the greater the amount of time for information processing (Williams et al, 1999). Expertise research (Abernethy, 1988; Williams et al, 1999) attributes this more efficient visual search behaviour to an elite athlete’s ability to use their greater contextual knowledge and experience to selectively attend to important visual cues and ignore less important cues, in turn increasing their visual search efficiency. Research has also atrributed greater contextual knowledge and experience to more fixations of shorter duration, but this may depend on the task being undertaken (Raynor, 2009).

While these findings are pertinent to the understanding of sport expertise, little research has investigated changes in visual search behaviours that occur through decision-making training, or how/if these changes or improvements are retained following a period of no training. Sailer et al. (2005) investigated the changes in gaze behaviour with the learning of a visuomotor task. Participants were asked to hold a small apparatus between their hands and use it to control a cursor on the screen that could be moved to hit targets as they were displayed. Eye movement recordings were analysed and the findings were broken down into phases of learning for the visuomotor task and the changes to gaze behaviours at each phase. In the beginning phase, gazes predominantly followed the cursor. In the second learning phase, with improved target hit rates came gaze fixations on specific cursor points. In the third and final learning phase, where participants were quite sufficient at the task, gazes shifted directly to the target. These findings demonstrate that gaze behaviour changes as tasks are learned and provides a foundation for the current research to adapt to the sport-training environment.

The current research investigated changes in the visual search behaviour of elite AF athletes as a result of a speeded video-based decision-making training intervention (see Lorains et al., 2013 [Chapter Two of this thesis]). Two video speed conditions were used and compared to a control group, who received no training. One group was trained in ART video speed and the other in normal speed video. Based on what is known about elite athlete visual search and changes throughout learning, it was hypothesised that the decision-making training intervention as a whole would increase visual search efficiency compared to the control group. An increase in visual search efficiency was measured by a decrease in the number of fixations and a higher fixation duration. This change would suggest that participants are developing the ability to tend to only relevant cues in the stimulus, rather than attempting to process all information presented. As outlined in Chapter 1, it would suggest that participants are 'doing more with less' (Muller, Abernethy & Farrow, 1996). Given the time constraints in the ART condition, it was hypothesised that participants would have a greater need to become more efficient in their visual search strategy and, thus, that this would increase over the course of training more rapidly in the fast speed than normal speed group. As a results of this, it would be expected that, if the elite fast speed group were performing more automatically, that they would need to fixate on the best option earlier in the visual search, if they were to maintain accuracy. The nature of the task will also need to be considered. Given the small sample size, it will be difficult to suggest a generalised approach, and this is an aspect for future research to consider, as discussed within the conclusions.

Method

Participants

Six male elite AF athletes were involved in eye movement tracking while completing a video-based decision-making training intervention (for full results of this intervention, see Lorains et al., 2013 [Chapter Two of this thesis]). There were three groups (ART video speed, normal video speed and control group) with two athletes per group. The small sample number is due to the logistical issues of collecting eye movements of the full training intervention of 45 athletes. Given the time it takes to set up, calibrate and test, and the time available in the athlete training schedule, it was not possible to include more than six athletes. However, despite these limitations, all participants were from the same AFL club and consistently playing at the highest level of competition in the sport, with a mean age of 24.1

years and 3.4 mean years playing at this level. The University Ethics Committee approved all procedures, and all participants provided informed consent prior to the collection of data.

Procedure

Decision-making task. This data was collected as a part of the larger training intervention study (see Chapter 2 of this thesis). Participants were randomly assigned to either ARTT (completed test clips in 1.5 times normal speed), normal speed training (completed in normal speed) or control (no training). Decision-making clips were sourced from a broadcast camera view of AFL game-day footage; each clip was between 4.3 and 5.4 seconds in duration. Each clip was only seen once; pre- and post-test clips were all new. Decisions were made for the team that was in possession of the ball, moving into attack (inside 50 plays), kicking out from defence (kick-ins) and plays throughout the midfield. Clips were edited using Adobe Premiere Elements version 9.0, using the time stretch feature to increase the speed to 1.5 for the ARTT condition. Three AFL coaches independently rated each clip by awarding three, two and one point(s) based on their opinion of the best three decisions available in each clip. E-Prime V2 Professional software was used to present and collect data on individual 17-inch screen laptops. See Figure 4.1 for a photograph of the testing set up.

Figure 4.1: *Testing set up.*

During testing, participants watched each video clip in their designated speed (14 clips per session, including two warm-up clips). Once the video paused, participants heard a beep and had three seconds to respond via mouse-click to make their decision for the player in possession of the ball. Options included other players, an area of the ground, in between the goal posts, a space for the player to run on to or play-on themselves (click on the player). Participants had to make their decision as quickly as possible once they heard the first beep. Their decision accuracy was assessed based on the coach ratings of each clip. A zero was given for any answer outside of these, or if they took longer than three seconds to respond.

Visual search data. The Mobile Eye (Applied Science Laboratories, Bedford, MA) eye movement recorder was used to record the visual search strategies of the six athletes. The Mobile Eye collected visual search data at a rate of 30Hz. Participants were calibrated to a nine-point stationary screen and point-of-gaze relative to those locations was identified using the displacement between the pupil and corneal reflex (Vaeyens et al., 2007), in a field of view, in this case the video-based decision-making task with spatial accuracy of 0.5 degrees and a 0.1 degree visual angle of precision (Panchuk & Vickers, 2009). Calibration was conducted before every individual decision-making training session and monitored throughout testing to ensure calibration was maintained.

Visual search behaviours were coded using Quiet Eye Solutions software (QES; Calgary, AB). Three gaze measures were used in the analysis, as defined by Vickers (2007). First, a fixation was defined as a gaze that remained still on an object or location for more than three frames (99.99 ms). Fixation locations included ball, opponent, teammate, correct option one, correct option two, correct option three, space on the field, goal posts and player in possession of the ball. Second, a saccade has been defined as a gaze that moves from one location to another in less than three video frames (66.66 ms). The last gaze behaviour used in coding was ‘other’. This was used when the point-of-gaze was outside of the screen area or not visible for coding. Due to some difficulties in completing satisfactory calibration of the Mobile Eye, visual search data was analysed for four video sessions, as indicated with an asterisk in Table 4.1.

Table 4.1

Timeline of Training Intervention

	Group		
Week	Fast (n = 2)	Normal (n = 2)	Control (n = 2)
1	Pre-Test* Training 1	Pre-Test* Training 1	Pre-Test*
2	Training 2	Training 2	No Training
3	Training 3*	Training 3*	No Training
4	Training 4	Training 4	No Training
5	Training 5	Training 5	No Training
6	Post-Test*	Post-Test*	Post-Test*
7–8	No Training	No Training	No Training
9	Retention Test*	Retention Test*	Retention Test*
10–18	No Training	No Training	No Training
19	Retention Test	Retention Test	Retention Test

* Indicates analysis of eye movements

Data Analysis

Mixed between-within subjects repeated measure ANOVAs was performed.. The following dependent variables were analysed: decision accuracy (three, two, one and zero points), mean number of fixations and average duration of these fixations (s). Independent variables were group (ARTT, normal, control) and test time (pre, training three, post and retention test one). Mean values and standard deviations are displayed in Table 4.2. Fixation locations (percentage of the total viewing time spent on each location) were analysed individually using a mixed between-within analysis method.

Table 4.2

Individual Scores of Decision-Making Accuracy, Fixation Number and Fixation Duration (s)

Measure / Participant	Pre-Test	Training 3	Post-Test	Retention Test 1
Accuracy				
Above Real Time 1	9	22	34	33
Above Real Time 2	8	20	25	27
Normal Speed 1	15	19	30	26
Normal Speed 2	14	20	27	25
Control 1	18	-	16	14
Control 2	11	-	16	9
Fixation Number				
Above Real Time 1	10.87	5.27	6.08	8.33
Above Real Time 2	9.36	5.36	8.61	10.27
Normal Speed 1	11.42	10	11.58	12.21
Normal Speed 2	6.83	8.67	10.66	10.33
Control 1	7.92	-	9.81	11.43
Control 2	8.42	-	9.72	12.56
Fixation Duration (s)				
Above Real Time 1	.95	.93	1.08	1.1
Above Real Time 2	1.09	1.02	1.06	1.0
Normal Speed 1	1.13	1.08	1.00	1.1
Normal Speed 2	.89	.94	.89	.98
Control 1	1.03	-	1.14	1.0
Control 2	1.1	-	1.08	.92

Two coders were used to code eye movement data and assess its reliability. Both coders coded 75% of the data and, for reliability, coded all participants from the pre-test, post-test and retention test. The third training session was the only session not dual coded. The kappa statistic was used to measure the reliability of coding based on the ranges: < 0: less than chance agreement; 0.01–0.20: slight agreement; 0.21–0.40: fair agreement; 0.41–0.60: moderate agreement; 0.61–0.80: substantial agreement and 0.81–0.99: almost perfect agreement (Landis & Koch, 1977). The inter-rater reliability for fixation number, k = .94, fixation duration k = .92 and fixation location k = .89 were all classified as almost perfect agreement.

Results

Decision Accuracy

The within subjects analysis results revealed no significant main effects, Wilks Lambda = .014, F (3, 1) = 22.74, p = .153, partial eta squared = .986. No interactions were found either, Wilks Lambda = .002, F (6, 2) = 7.26, p = .126, partial eta squared = .956. Tests of between-subjects effects revealed a significant effect of group, p = .022, partial eta squared = .923. Further, post-hoc tests showed that the intervention groups were more accurate in their decisions than the control group, p = .027. This reflects the findings of the complete decision-making training program (see Lorains et al., 2013 [Chapter Two of this thesis]), wherein the ART and normal speed training group improved more greatly than the control group, and retained these results following a period of no training.

Fixation Number

The within subjects analysis results for the number of fixations revealed no significant main effects, Wilks Lambda = .007, F (3, 1) = 44.34, p = .110, partial eta squared = .993. No interactions were found, Wilks Lambda = .004, F (6, 2) = 7.78, p = .183, partial eta squared = .935. Tests of between-subjects effects also revealed a non-significant effect of group, p = .120, partial eta squared = .757.

Fixation Duration

The fixation duration within subjects analysis revealed a significant main effect, Wilks Lambda = .001, F (3, 1) = 406.74, p = .036, partial eta squared = .999. Significant interactions were also found, Wilks Lambda = .000, F (6, 2) = 23.08, p = .042, partial eta squared = .986. Tests of between-subjects effects also revealed a significant effect of group, where the ART and normal speed training group had longer average fixation durations following the training phase than the control group, p = .043, partial eta squared = .878.

Fixation Location

The mixed between-within subjects analysis for fixation locations revealed a significant main effect of time, F (3, 1) = 2617.3, p = .014, partial eta squared = 1.0. An interaction between time and group was also found, F (6, 2) = 75.94, p = .013, partial eta squared = .996. Post-hoc tests revealed that the fast speed video training group spent significantly less time fixating on the player in possession of the ball following training, p = .013, compared to normal and control groups. There were no significant differences found at pre-test, training session three or post-test for fixation locations, best option (p = .06), second best option (p = .74) or third best option (p = .39). At the retention test, the ART group spent significantly more time fixating on the best option compared to the normal speed and control groups, p = .046. Further, the normal speed training group spent more time fixating on the best option compared to the control group, p = .028).

Discussion

This current research assessed the changes in visual search behaviour throughout a speeded video-based decision-making task. Building on previous learning and eye movement research that showed changes in visual search throughout the learning process (Sailer et al., 2005), it was hypothesised that generally the decision-making training intervention would increase the efficiency of visual search processes, and that eye movements would, therefore, change throughout the training. Given the speeded nature of the ART condition, it was hypothesised that this training intervention group would become more efficient earlier in training faster than the normal speed or control group. Each of the elite athletes completed the video-based training intervention in either a normal speed video group, an ART video group or the control group (received no training). Eye movements were collected at the pre-test, at the third training session, the post-test and the retention test, which was completed two weeks after the post-test. This method allowed tracking of the changes in visual search behaviours throughout the training and following a period of no training, a highlight of this research that previous research has not addressed. Generally, the hypotheses were supported by the data.

The change in average duration of fixations increased for those in both intervention groups. This is in line with previous expertise research that states that experts have longer fixation durations than novices (Helsen & Starkes, 1999). These results suggest that this may be an aspect of expertise that can be trained using video-based training. While no significant differences were found in the average number of fixations, there was a trend for the ART group to use fewer fixations following training compared to the other groups. This finding is in line with a key characteristic of expert visual search strategies (Helsen & Starkes, 1999).

It was notable that the fixation on locations changed following testing. This is illustrated with the ART group fixating on the best option for longer compared to the normal speed training group and the control group. This finding suggests that training can increase the visual search efficiency, allowing participants to sooner identify the best decision. It was hypothesised that a change could occur in visual search strategy for the ARTT group due to the speeded nature of the task; it creates the need for a higher level of automaticity and processing efficiency. Lorains et al. (2013 [Chapter One of this thesis]) explored this and attributed athletes' performance in ART simulations to these key characteristics of expertise, automaticity and processing efficiency.

With any research using gaze behaviours, however, it is important to consider the difficulty in equating fixation durations with attention. Simply, it is difficult to reliably infer that cognitive processes can be fully explained by gaze behaviours, yet it is one method to track the cognitive processes that may contribute to attentional resources of experts.

The logistical limitation of a small sample size of only six participants made it difficult to uncover significant results, as might be expected with higher sample sizes. This should be taken into considreation when making assumptions from this data presented. Individual data was also presented, to give the reader insight into individual performance, given the difficulty in making assumptions from groups of two participants. Despite this, it is shown that the methods are sound. Further, the results suggest that regardless of video speed, video-based training can change an elite athlete's visual search strategies. This finding alone is new to the sport research domain, as this research is the first to track eye movements throughout a video-based decision-making training intervention. This method provides insights into real time cognitive processing and changes as a result of learning and performance improvements in the elite training environment. This research provides a base for the future in tracking changes in visual search strategies throughout training interventions. Future research should focus on speeded video as the training intervention and visual search strategies as the process-tracing method and investigate the differences between expert and novice participants.

Chapter 5: General Discussion

This thesis raised the question: 'how can we effectively train sport decision making in a "game-like" environment while maintaining the benefits of video-based training?' A thorough investigation was undertaken, employing a range of different aspects of performance. Various video speeds were tested and then developed into a training intervention. ARTT, a method widely used in aviation (Guckenberger et al., 1993; Kolf, 1973), was utilised when developing the training intervention to examine the changes in decision-making performance when training in speeded video and normal speed. Throughout training, eye movement recordings were analysed, providing insight into different aspects of decision making and the mechanisms that may drive elite performance. In addition, a decision-making-specific notational analysis system was designed to measure transfer of performance into live match situations. The notational analysis system separated the physical and cognitive components of decision making to provide a more precise performance measure. Together, these aspects of the research provided a solid methodological approach and comprehensive evidence towards answering the question posed.

The first aim of this thesis was to investigate the differences in expert and novice decision-making accuracy as affected by increased video speed. This research was the first to use speeded video as a process-tracing method for expertise. Supplementary to this aim was the investigation of an optimal speed for a video-based training intervention. The speeded video provided a method to trace the influence of automaticity and processing efficiency on performance. Early research from Fitts and Posner (1967) suggests that elite athletes perform with a higher level of automaticity than do novices. Automaticity is applied generally to physical skills (e.g. Beilock et al., 2004; Beilock et al., 2002); it has also been used to explain cognitive skills such as decision making. Johnson and Raab (2003) highlight that applying time pressure to a decision-making task may increase accuracy, identifying time pressure as a potential factor in performance.

The use of the EPA was vital in providing a more in-depth understanding of expertise and decision making. Williams and Ericsson (2005) state that for true characteristics of elite performance to be elicited, a task needs to be representative of the real performance domain. Before this point is reached, the mechanisms that drive expert performance need to be identified. This research has built upon previous research that has identified expert-novice differences in sport decision making (Abernethy, 1996; Lorains & MacMahon, 2009; Starkes & Lindley, 1994), and used a speeded video to understand the mechanisms of elite decision making.

Using speeded video as a process-tracing method ensured all information was still presented and added time pressure to the information processing requirements of the task, forcing participants to act with a higher level of automaticity in order to be accurate in their decisions. Results revealed that, as expected, the elite athletes had superior decision-making accuracy over the sub-elite and novice participants in a single test of performance. This is in line with the abundance of previous decision-making research (Abernethy, 1996; Blomqvist, Vanttinen & Luhtanen, 2005; Lorains & MacMahon, 2009; Lorains et al., 2013 [Chapter One of this thesis]; McMorris, 1997; Starkes & Lindley, 1994).

A major finding from Chapter One was that as the video speed increased, so did the decision-making accuracy of the elite participants, contrary to the sub-elite and novice participants, who declined in performance at this point (1.5 video speed). These performance differences were attributed to an expert's ability to perform with a higher level of automaticity and processing efficiency, an underlying expert advantage. It is important to note that automaticity was not directly measured in this research, and furthermore, these findings are evidence to support one theory of why performance improved. In order to directly measure the athletes level of automaticity and attentional resources used for the task, a dual-task paradign would need to be employed. This has been identified as the next step in this line of research.

The increase of elite player decision accuracy at the faster speeds, coupled with the ‘game-likeness’ rating at the 1.5 speed, suggests that the faster video speed is more representative of the real tasks and, therefore, elicits true characteristics of elite performance. It is important to note that the sub-elite group also rated the video speeds of 1.5 as being most ‘game-like’. As the video speeds reached 1.5 and higher, the elite group improved in performance, whereas the sub-elite group significantly declined in performance. The novice group may have found the task too difficult overall, scoring low regardless of video speed. These findings highlight the important practical implication that an optimal video speed may differ according to expertise or experience level. Different video speeds will alter the level of cognitive training load, depending on skill level.

Functional overreaching is a method of athletic performance enhancement, more often involving physical aspects of performance. Functional overreaching is when there is an increase in training intensity that may lead to an initial decrease in performance, but if managed correctly, can create a super-compensation effect. The final result being increased performance above that of initial levels (Halson & Leukendrup, 2004). The decline in sub-elite performance as training intensity increased (speeds higher than 1.5) could have been a result of the decrease in performance before the super-compensation effect occurred. In view of the fact that this research proceeded to train elite athletes only, this finding provides a strong base for future research to investigate the sub-elite expertise level for training purposes.

The second aim of this thesis was to use the optimal training speed of 1.5 in a training intervention. The ARTT group improved in performance faster than the normal speed group and, further, retained these performance improvements for a longer period. These performance improvements were attributed to the speeded video creating a ‘game-like’ training scenario, increasing the psychological fidelity, providing a higher level of cognitive processing similarities between training and match situations. Lee (1988) suggests that by training in an environment that has similar cognitive processing demands, a greater level of transfer from training to match situations will be evident.

The use of video-based decision-making training to elicit accurate measures of real performance is often criticised, as a school of research describes that 2D video does not look like real game situations, and therefore will not elicit real behaviours or results (Araujo et al., 2006). Simulation fidelity is not only how a simulation looks (physical fidelity) but also how a simulation feels to operate within; this is termed psychological or experiential fidelity (Stoffregen et al., 2003). The use of ARTT, 1.5 video speed increases the psychological fidelity of the decision-making simulations. This is supported by the empirical data from the ‘game-likeness’ ratings; providing evidence that ARTT can provide a higher fidelity training environment compared to normal speed video, allowing athletes to feel more like they are making decisions in a real match situation.

A design feature of this training intervention was the inclusion of three groups allowing insight not only into the effects of video-based decision-making training, but also into the mechanisms of increased processing efficiency used by those elite athletes in the ARTT group. This is evident from their superior improvement in and retainment of decision accuracy performance. The inclusion of retention tests, one at two weeks and one at ten-weeks following the post-test also provided information on the retention of performance improvements for each group. The results showed that the ARTT group retained their performance improvements for a longer period than the normal speed or control group.

ARTT has a number of important practical and theoretical benefits. It is cost and resource effective, with the need for only a computer or laptop screen and software, and without the need for large screens or multiple players to generate the scenarios. Importantly, it creates a higher fidelity simulation, as reported by pilots and athletes, who rate fast speed video more indicative of real game performance compared to that of normal speed (Guckenberger et al., 1993; Kolf, 1973; Lorains et al., in press). From a coaching point of view, having a higher fidelity simulation allows coaches and researchers to maintain the benefits and control that video-based tasks provide. By training in video simulations, coaches do not require large scale equipment, they do not need to be present, nor do they need large numbers of players to set up live scenarios. Injured players can also be involved as it is 'off the feet' training.

In addition, a secondary characteristic of performance that was measured included the analysis of eye movement recordings. Real time visual and cognitive processes can be exposed (Henderson, 2011; Raynor, 1998) by analysing eye movements, furthering knowledge of what drives expert performance during training or learning. This was shown in an investigation into changes in eye movements as a result of learning a physical skill that was completed for a visuomotor task (Sailer et al., 2005). Eye movements changed with different learning and skill refinement phases, leading to participants spending more time fixating on the final target in later phases. These findings from Sailer and colleagues provided a good foundation for this current research to further build on and adapt to the sport-training environment.

Despite the small sample size for eye movement analysis, the changes in eye movements as a result of ARTT for decision making were apparent from the increased average fixation time and the change in average time fixating on various locations. Following the training intervention, those trained in ARTT, compared to normal and control groups, spent more time fixating on the best option rather than the person in possession of the ball. These changes were attributed to the increased processing efficiency of those in the ARTT group, because they were able to faster process the information and further identify and fixate on the best response, another key characteristic of expertise, as discovered by both speeded video and eye movement recordings.

The third aim of this thesis in the investigation of speeded video and decision making was to create a tool to reliably measure transfer of performance gains. As with any training intervention, it is important to be able to show that performance improvements transfer into live match situations (Starkes & Lindley, 1994). Williams and Ericsson (2005) state that this aspect is often overlooked by researchers due to the difficulty in the design of such measures. Attempts have been made previously (e.g., Thiffault, 1974; Bruce et al, 2009). However, these attempts have not successfully measured the cognitive aspects of decision making in live game situations.

This thesis is the first to measure transfer from a video-based decision-making training intervention, using a specifically designed decision-making notational analysis system. The findings of this transfer test support the use of video-based decision-making training generally, as those who completed training showed greater transfer than those in the control group. Interestingly, the trend for the ARTT group showed that they more frequently selected the best option in their on-field performance following ARTT. The sensitive scoring system allowed this insight into performance changes throughout the season. An additional part of this aim was to design a reliable notational analysis system that allowed specific performance analysis of the cognitive aspects of decision-making performance, separate from the physical execution components. Previous research has linked successful decision making with successful skill execution (Bruce et al., 2009). The findings of this thesis highlights the importance of separating the two components of decision making in order to gain a true reflection of decision-making performance. The high inter-rater and intra-rater reliability reflected the robustness of the system and also highlighted the importance of using suitably trained performance analysts.

The design features of this notational analysis system are that it includes all facets of performance, decision accuracy, facing different options and different levels of defensive pressure, skill execution type and effectiveness, as well as match context. The benefit from a practical coaching point of view is that each of these aspects can be used together or separately. This allows coaches and researchers to measure purely the quality of their decisions, without this being influenced by their physical skill set. Interestingly, those who completed training tended to choose the best option more often compared with the control group. This trend, transferred onto the field, provides exciting platforms for the notational analysis system to be further tested with larger sample sizes in the future.

The use of speeded video as a process-tracing method allowed the identification of automaticity and processing efficiency as possible mechanisms that drive elite performance on a video-based decision-making task. This was further supported by the changes in visual search throughout video-based training, with participants displaying a more efficient search pattern following training. The optimal speed used for training provided a high fidelity simulation, producing greater and faster performance gains and retention rates. The measurement of transfer saw general video-based training transfers; more specifically, those trained in ARTT tended to choose the best option more frequently. Also, the results reiterated the importance of separating the physical and cognitive components of decision making to gain true insight into performance. The combined results and methodical approach presented within this thesis provides solid empirical evidence to support speeded video and ARTT as training tools for decision making, with the support of a reliable decision-making specific notational analysis system.

Chapter 6: Contributions to Knowledge

This thesis designed and applied a methodical framework for the investigation of speeded video as a training tool for decision making in sport. Different methods were used: elicitation of expert-novice differences, a test of different video speeds, a training intervention, eye movement recordings and transfer tests to gain a detailed representation of performance under speeded video conditions. The main contributions to knowledge of this thesis are in five main sections: identification of optimal training speeds, ARTT intervention, decision-making notational analysis system, eye movement tracking and sport-specific knowledge.

Identification of Optimal Video Training Speeds

This research used speeded video as a process-tracing method in a video-based decision-making task to further understand the mechanisms underlying expert performance. Noticeably, all previous research using speeded video is in excess of two decades old (Guckenberger et al., 1993; Kolf, 1973), and further research in this area has not been published, despite the fact that it may be used within different industries. This highlights the need to further examine speeded video simulations for superior decision-making results.

While the use of the ARTT method is not new to sport (Lorains & MacMahon, 2009), it has not been widely used or thoroughly investigated for decision making. This current research was the first to test a variety of video speeds to measure performance. A structured methodological approach was used, building on previous research that tested only one or two speeds (Guckenberger et al., 1993; Kolf, 1973; Lorains & MacMahon, 2009) by testing six different video speeds. The inclusion of a large number of speeds, including slow speed, allowed a more comprehensive understanding of how video speed may dictate performance. Further, an insight into which video speed in particular felt most ‘game-like’ when making a decision was revealed.

To date, no research has tested different speeds in an attempt to identify an optimal speed for training that increases the fidelity of the simulation for athletes. Kolf (1973) used 1.5 speeds in aviation simulations; this speed was only compared to normal speed. Although a positive step, Kolf's research only provided anecdotal evidence from a small sample of pilots regarding their feelings towards simulations in such speed. Lorains and MacMahon (2009) were the first in sport to use speeded video simulations, but again, this research only used 1.5 and normal speeds (based on the work by Kolf, 1973), and was purely investigating differences in decision accuracy between elite and sub-elite athletes and novice participants. Additionally, there were no ratings regarding athlete perception of decision making over the two speeds.

This research was the first to empirically rate perceptions of video speeds as it related to making decisions in real match situations. The finding of 1.5 speeded video as being the most 'game-like' when making decisions is supported by previous research (Guckenberger et al., 1993; Kolf, 1973). Linking this to the performance outcomes, 1.5 speeded video was also the first point of significant difference between the elite participants and the sub-elite/novices for decision accuracy. Additionally, it was the speed identified by both elite and sub-elite athletes as feeling most 'game-like' when making decisions.

All of the research to date using speeded video simulations has suggested, anecdotally, that such conditions feel more like the real thing. A major contribution from this research is that there is empirical data to support this claim and performance improvements to suggest a possible optimal training speed for elite athletes,

This finding of 1.5 speed as feeling most 'game-like' is an evidence-based starting point for future research using ART simulations. This provides two interesting avenues for future research to explore, as well as an important consideration. First, the video speed of 1.5 as a challenge point for training sub-elite athletes. Second, to further explore elite athletes with higher video speeds, in order to investigate if the performance increases continue with the speed increase. Finally, the finding highlights that skill level needs to be considered when conducting interventions, because skill-based differences exist for optimal video speeds.

Above Real Time Training Intervention

Using the optimal training speed identified in this research, a training intervention was designed using normal speed, 1.5 speed (ARTT) and a control group. Results showed that those trained with fast speed video performed more accurately, improved earlier (significant differences from the second training session) than the normal speed group and possessed higher retention rates compared to the normal speed training group. These findings support Schneider (1985, as cited in Guckenberger et al., 1993), who describes that those trained at least in part in ART would have faster acquisition. Through training in ART, specifically 1.5 video speed, athletes are exposed to a more 'game-like' feeling of making decisions, which allows them to perform with a higher level of automaticity, taking advantage of their superior processing efficiency. The greater performance improvements in the ART group and their retention rates also supports Guckenberger et al. (1993), who suggested that 1.5 could be an optimal video training speed because it increases the fidelity of the simulated environment.

Video-based decision-making training can be difficult to design (Starkes & Lindley 1994), and as a result, much decision making research uses one-off tests of performance to measure decision-making accuracy, often with the aim of eliciting expert-novice differences (e.g., Blomqvist et al., 2005; McMorris, 1997). Also, the methods of video-based research are often criticised because it is not life-like compared to perception-action coupling or in-situ decision-making assessment methods (Araujo et al., 2006). This possibly intensifies the difficulty in designing a sound video-based decision-making training intervention. Using speeded video creates a higher fidelity simulated training environment while maintaining the well-documented advantages of video-based testing and training (see, Starkes & Lindley, 1994). The results presented in this thesis provide strong support for a method that begins to close the gap between video-based training and perception-action coupling training approaches.

ARTT has a number of important practical and theoretical benefits. First, it is cost and resource effective, only requiring a computer or laptop screen and software and not needing large screens or multiple players to generate the scenarios. Second, and importantly, it creates a higher fidelity simulation than normal speed video, as reported by pilots and athletes, who rate fast speed video more indicative of real life and game performance compared to that of normal speed (Guckenberger et al., 1993; Kolf, 1973; Lorains et al., 2013 [Chapter One of this thesis]). Third, from a coaching point of view, a higher fidelity simulation allows coaches and researchers to maintain the benefits and control (e.g., little set up, not physically taxing and inclusive of injured players) that a video-based task provides The use of ARTT also allows coaches and researchers to focus and separate the skill execution from the cognitive processes of decision making for training purposes. The training intervention implemented in this thesis is the first within sport. As such, a solid platform for future investigations has been created. The results themselves provide solid evidence of a sound training method for decision making.

Decision-Making Notational Analysis System

Any training intervention should be able to measure transfer of performance improvements onto the field (Starkes & Lindley, 1994). This can be measured using performance analysis methods. James (2006) suggests that notational analysis systems should incorporate all facets of performance, and most importantly, how they all affect each other. Limited research has included tests of transfer for decision making. Thiffault (1974) used wooden cut-outs of hockey players to simulate a real hockey match situation and measured transfer from a static slide training method. Bruce et al (2009) developed a decision-making assessment tool that linked an accurate decision to the outcome of the skill execution.

This research is among the first in sport to measure transfer from video-based decision-making training interventions, using a specifically designed assessment tool for decision making, into live game situations. This transfer assessment tool is one of the first to assess in-game decision-making quality, where the skill execution and cognitive components of decision making are separated. Additional highlights are the inclusion of aspects such as level of pressure and number of options available. The sensitivity of the analysis system allowed insight into the trends that followed training: athletes were choosing the best rather than poorer option more often later in the season than they were earlier in the season.

The design of this notational analysis system for decision making is practical for implementation by coaches and performance analysts. As James (2006) suggests, it incorporates all aspects of decision-making performance, yet allows coaches to investigate each independently or as a whole. The sensitive nature of the decision accuracy ratings (three, two, one and zero point[s]) allowed greater insight into the quality of decisions being made throughout the season. Identifying that athletes were choosing the best option more often after the training intervention is important, at the practical level, for coaches to see improvement.

A major feature of this notational analysis system is its flexibility to be adapted to different sports and aspects of performance (umpire or athlete). The comprehensive nature of this tool establishes a strong avenue for future research to investigate the interaction between different performance measures. As this study had low numbers, future research could investigate larger samples over a larger period to gain a truer reflection of team and individual performance.

Eye Movement Tracking

The inclusion of eye movement analysis allowed a more comprehensive understanding of elite performance under speeded video conditions. To date, no research in sport has investigated eye movements during speeded video tasks, and more specifically, none have tracked performance throughout training. Including this in the design of the current research allowed insight into real time attention focus and cognitive processes throughout the decision-making process. Using eye movement tracking in this way is in line with previous research that has used eye movement recordings as a method to elicit expert-novice differences during physical and cognitive based tasks (e.g., Dicks et al., 2010; Roca et al., 2011; Vaeyens et al., 2007). Findings from such research revealed that experts had fewer but longer fixations than novices. Building on this, Sailer et al. (2005) specifically investigated changes in eye movements throughout learning. Results showed that eye movements can change with refinement and learning of a visuomotor skill. In the final stages of skill refinement, participants were spending the majority of time fixating on the final target. This thesis found evidence that supported previous research and built upon it by tracking changes though learning in a sport-specific environment.

The tracking of eye movements throughout the training intervention allowed an understanding of changes that occur as a result of video-based decision-making training. The results showed that following the training intervention, athletes had longer average fixation duration compared to the control group who received no training. The ARTT group also fixated for longer on the best option compared to the normal speed and control groups following training, rather than focusing on the person in possession of the ball. These eye movement changes found throughout training support previous expertise and learning research. The results and methods also provide a good foundation to include such aspects for future research.

Sport-Specific Knowledge

This thesis provides specific insights into the use of speeded video for decision-making training within AF. The systematic approach and thorough investigation creates a solid framework to be applied to other fast-paced invasion sports. The application of optimal video training speed may differ depending on the sport. For example, netball or tennis may benefit from 1.25 speed, given the incredibly fast-paced nature of the sport. This research has focused on optimal training speeds for elite athletes and provided solid evidence for a new training tool. Future research could focus more specifically on different skill levels. The video speed of 1.5 was identified as optimal for elite athletes, but this could also be appropriate for sub-elite athletes. A combination of speeds could also be investigated. Notably, the limited amount of ART research has been conducted in fast-paced invasion sports or fast aviation activities, so further investigation could examine an array of slower speed team sports or individual sports.

References

Abernethy, B. (1988). Visual search in sport and ergonomics: Its relationship to selective attention and performer expertise. *Human Performance, 1*(4), 205–235.

Abernethy, B. (1994). The nature of expertise in sport. In S. Serpa, J. Alves & V. Pataco (Eds.), *International Perspective on Sport and Exercise Psychology* (pp. 57–68). Morgantown, WV: Fitness Information Technology.

Abernethy, B. (1996). Training the visual perceptual skills of athletes: Insights from the study of motor expertise. *The American Journal of Sports Medicine, 24,* S89–S92.

Abernethy, B., Baker, J. & Cote, J. (2005). Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology, 19*(6), 705–718.

Araujo, D., Davids, K. & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise, 7,* 654–676.

Baker, J., Cote, J. & Abernethy, B. (2003). Sport-specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology, 15,* 12–25.

Beilock, S., Bertenthal, B., McCoy, A. & Carr, T. (2004). Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin and Review, 11*(2), 373–379.

Beilock, S., Carr, T., MacMahon, C. & Starkes, J. (2002). When paying attention becomes counterproductive: Impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experiential Psychology: Applied, 8*(1), 6–16.

Blomqvist, M., Vanttinen, T. and Luhtanen, P. (2005). Assessment of secondary school students' decision-making and game-play ability in soccer. *Physical Education and Sport Pedagogy, 10*(2), 107–119.

Bruce, L., Farrow, D., Raynor, A. & May, E. (2009). Notational analysis of skill expertise differences in netball. *International Journal of Performance Analysis of Sport, 9,* 245–254.

Dicks, M., Button, C. & Davids, K. (2010). Examination of gaze behaviours under in situ and video simulation task constraints reveals differences in information pickup for perception and action. *Attention, Perception and Psychophysics, 72*(3), 706–720.

Ericsson, K.A. (1996). Protocol analysis and expert thought: Concurrent verbalizations of thinking during experts' performance on represetative tasks. In K.A Ericsson, N Charness, P.J. Feltovish & R.R Hoffman (Eds), The Cambridge Handbook of Expertise and Expert Performance. New York: Cambridge University Press.

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

Farrow, D. & Abernethy, B. (2003). Do expertise and degree of perception-action coupling affect natural anticipatory performance? *Perception, 32*.

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

Fitts, P. M. & Posner, M. I. (1967). *Human performance*. Monterey, CA: Brooks/Cole.

Gabbett, T., Rubinoff, M., Thorburn, L., & Farrow, D. (2007). Teating and training anticipation skills in softball fielders. *International Journal of Sport Science & Coaching, 1(2),* p15.

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

Gilis, B., Helsen, W., Catteeuw, P., Van Roie, E. & Wagemans, J. (2009). Interpretation and application of the offside law by expert assistant referees: Perception of spatial positions in complex dynamic events on and off the field. *Journal of Sports Sciences, 27*(6).

Glockner, A. & Betsch, T. (2012). Decisions beyond boundaries: When more information is processed faster than less. *Acta Psychologica, 139,* 532–542.

Guckenberger, D., Uliano, K. & Lane, N. (1993). *Training high performance skills using above real-time training*. National Aeronautics and Space Administration, Dryden Flight Research Facility.

Halson, S. & Leukendrup, A. (2004). Does overtraining exist? An analysis of overreaching and overtraining research. *Sports Medicine, 24*(14), 967–981.

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

Heeter, C., (2003). Reflections on real presence by a virtual person. Presence, 12(4), 335-345.

Helsen, W. & Pauwels, J. M. (1992). A cognitive approach to visual search in sport. In Visual Search, D. Brogan & K. Carrs (Eds). London: Taylor and Francis.

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

Henderson, J. (2011). Eye movements and scene perception. In S. Liversedge, I. Gilchrist & S. Everling (Eds.), *The Oxford handbook of eye movements*. Oxford, England: Oxford University Press.

Hepler, T. & Feltz, D. (2012). Take the first heuristic, self-efficacy, and decision-making in sport. *Journal of Experimental Psychology: Applied, 18*(2), 154–166.

Hughes, M. & Bartlett, R. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences, 20,* 739–754.

Hughes, M. & Franks, I. (2004). *Notational analysis of sport: Systems for better coaching and performance in sport.* London: Routledge.

James, N. (2006). Notational analysis in soccer: Past, present and future. *International Journal of Performance Analysis in Sport, 6*(2), 67–81.

Johnson, J. & Raab, M. (2003). Take the first: Option-generation and resulting choices. *Organizational Behaviour and Human Decision Processes, 91*(2), 215–229.

Kolf, J. (1973). *Documentation of a simulator study of an altered time base*. (Unpublished manuscript). NASA Dryden Flight Research Facility, Edwards, CA.

Landis, J. & Koch, G. (1977). The measurement of observer agreement for categorical data. *Biometrics,* 33, 159–174.

Lee, T. (1988). Transfer-appropriate processing: A framework for conceptualizing practice effects in motor learning. In O. G. Meijer & K. Roth (Eds.), *Advances in psychology* (pp. 201–215). Elsevier.

Lorains, M. & MacMahon, C. (2009). Adapting the functional overreaching principle to cognitive skills: Expertise differences using speed manipulations in a video-based decision-making task. *Proceedings of the 12th World Congress of Sport Psychology (ISSP),* Marrakesh, Morocco.

Lorains, M., Ball, K. & MacMahon, C. (2012). Performance analysis of decision making in team sports. *Proceedings of the World Congress of Performance Analysis in Sport IX,* Worcester, England.

Lorains, M., Ball, K. & MacMahon, C. (2013). Expertise differences in a video decision-making task: Speed influences on performance. *Journal of Sport and Exercise Psychology, 14*, 293–297.

Lorains, M., Ball, K. & MacMahon, C. (2013). An above real time training intervention for sport decision making. *Psychology of Sport and Exercise, 14,* 670-674.

Lorains, M., Ball, K., MacMahon, C. & Mahoney, J. (2011). Above real time training for team invasions sports. *International Journal of Sports Science and Coaching, 6*(4), 537–544.

Lorains, M., Panchuk, D., Ball, K. & MacMahon, C. (submitted). The effect of an above real time decision-making intervention on visual search behaviour. *International Journal of Sports Science and Coaching.*

MacMahon, C. & McPherson, S. (2009). Knowledge base as a mechanism for perceptual cognitive tasks: Skill is in the details! *International Journal of Sport Psychology, 40*(4), 565.

MacMahon, C., Starkes, J. & Deakin, J. (2009). Differences in processing speed of game information in basketball players, coaches and referees. *International Journal of Sport Psychology, 40*(3), 403–424.

McMorris, T. (1997). Performance of soccer players on tests of field dependence/ independence and soccer-specific decision-making tests. *Perceptual and Motor Skills, 85*, 467–476.

McPherson, S. & Vickers, J. (2004). Cognitive control in motor expertise. *International Journal of Sport and Exercise Psychology, 2*(3), 274–300.

Muller, S., Abernethy, B. & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *Quarterly Journal of Experimental Psychology, 59,* 2162–2186.

North, J., Williams, A., Hodges, N., Ward, P. & Ericsson, K. (2009). Perceiving patterns in dynamic action sequences: Underpinning stimulus recognition and anticipation skill. *Applied Cognitive Psychology, 23*, 878–894.

Olmoa, A., Bouillot, N., Knight, T., Mabire, N., Redel, J., & Cooperstock, J. (2012). A high fidelity orchestra simulator for individual musicians' practice. *Comuper Music Journal, 36(2),* 55-73.

Oslin, J., Mitchel, S., & Griffin, L. (1998). General performance Assessment Instrument (GPAI): Development and preliminary validation. *Journal of Teaching in Physical Education*, 17, 231-243.

Panchuk, D. & Vickers, J. N. (2006). Gaze behaviours of goaltenders under spatial-temporal constraints. *Human Movement Science, 25*, 733–752.

Phillips, M. & Edelman, J. (2008). The dependence of visual scanning performance on search direction and difficulty. *Vision Research, 48*(21), 2184–2192.

Raab, M. & Johnson, J. G. (2007). Expertise-based differences in search and option-generation strategies. *Journal of Experimental Psychology, 13*(3), 158–170.

Raynor, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*, 372–422.

Regenbrecht, H., & Schubert, T., (2002). Real and Illusory interactions enhance presence in virtual environments. *Presence, 11(4)*, 425-434.

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

Sailer, U., Flanagan, J. R. & Johansson, R. (2005). Eye-hand coordination during learning of a novel visuomotor task. *The Journal of Neuroscience, 25*(39), 8833–8842.

Savelsbergh, G. J. P., Williams, A. M., Van Der Kamp, J. & Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences, 20*(3), 279–287.

Starkes, J. L. & Lindley, S. (1994). Can we hasten expertise by video simulation? *Quest, 46*, 211–222.

Stoffregen, T., Bardy, B., Smart, L. & Pagulayan, R. (2003). On the nature and evaluation of fidelity in virtual environments. In L. J. Hettinger & M. W. Haas (Eds.), *Virtual and adaptive environments: Applications, implications, and human performance issues* (111–128). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Thiffault, C. (1974). Tachistoscopic training and its effect upon visual perceptual speed of ice hockey players. *Proceedings of the Canadian Association of Sport Sciences*, Edmonton, Alberta.

Thiffault, C. (1980). Construction et validation d'une measure de la rapidite de la pensee tactique des joueurs de hockey sur glace. In C. H. Nadeau, W. R. Halliwell, K. M. Newell & G. C. Roberts (Eds.), *Psychology of Motor Behaviour and Sport* (pp. 643–649). Champaign, IL: Human Kinetics.

Vaeyens, R., Lenoir, M., Williams, A. M. & Philippaerts, R. M. (2007). Mechanisms underpinning successful decision making in skilled youth soccer players: An analysis of visual search behaviours. *Journal of Motor Behaviour*, *39*(50), 395–408.

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

Vickers, J. (2007). Quiet Eye Solutions (Version 1.0.2) [Computer software]. Calgary, AB.

Vickers, J., Livingston, L., Umeris-Bohnert, S., & Holden, D. (1999). Decision training: The effects of complex instruction, variable practice and reduced delayed feedback on the acquisition and transfer of a motor skill. *Journal of Sports Sciences, 17(5),* 357-367.

Vidulich, M., Yeh, Y. and Schneider, W. (1983). Time Compressed Components for Air Intercept Control Skills, Proceedings of the 27th meeting of the Human Factors Society, 161-164.

Ward, P., Farrow, D., Harris, K., Williams, M., Eccles, D. & Ericsson, K. A. (2008). Training perceptual-cognitive skills: Can sport psychology research inform military decision training? *Military Psychology, 20*(1), 71–102.

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

Williams, A. M., Ward, P., Knowles, J. & Smeeton, N. (2003). Anticipation skill in a real-world task: Measurement, training and transfer in tennis. *Journal of Experimental Psychology: Applied, 8*(4), 259–270.

Williams, A. M., Davids, K. & Williams, J. G. (1999). *Visual perception and action in sport*. New York, United States of America: E & FN Spon.

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

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

Wisbey, B., Montgomery, P., Pyne, D. & Rattray, B. (2010). Quantifying movement demands of AFL football using GPS tracking. *Journal of Science and Medicine in Sport, 13,* 531–536.

Appendix

Consent Forms

Information Forms

Melbourne Football Club Letter of Support

13 November 2009

To The Research Ethics Committee,

On behalf of the Melbourne Football Club, we support the research to be conducted by Dr Clare MacMahon, Dr Kevin Ball and Ms Megan Lorains.

We will aid in providing participants, and the use of facilities at the Melbourne Football Club, such as suitable space for testing and data collection.

Regards,

Brad Gotch

Coaching and Development Staff

Melbourne Football Club

Athlete Feedback Example

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

AFL DECISION MAKING TRAINING 2011

PLAYER NAME
PLAYER NUMBER
INTERVENTION GROUP

YOUR RESULTS

	Pre-Test	Training 1	Training 2	Training 3	Training 4	Training 5	Post Test	Retention Test
Average Score (%)	38.89	50.00	69.70	69.44	69.44	81.82	94.44	91.67
Average Decision Time (s)	1.83	1.99	1.71	1.45	1.65	1.27	1.66	1.64

Accuracy Overall Improvement = 55.56 %
Decision Time Improvement = 0.17 seconds

TEAM RESULTS

	Pre-Test	Training 1	Training 2	Training 3	Training 4	Training 5	Post Test	Retention Test
Group Average Score (%)	36.85	45.37	60.00	61.85	70.93	78.99	78.57	79.27
Group Decision Time (s)	1.51	1.82	1.55	1.50	1.47	1.53	1.68	1.28

Accuracy Overall Improvement = 41.72 %
Decision Time Improvement = -0.17 seconds