Assessing the acute effects of a video-based warm-up on the perceptual and decision-making components of agility in rugby football using 3D motion analysis

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Assessing the acute effects of a video-based warm-up on the perceptual and decision-making components of agility in rugby football using 3D motion analysis

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BSportExSc

A thesis submitted for the degree of
Master of Science (by research) at
Southern Cross University

School of Health & Human Sciences

April 2014
Declaration

I certify that the work presented in this thesis is, to the best of my knowledge and belief, original, except as acknowledged in the text, and that the material has not been submitted, either in whole or in part, for a degree at this or any other university.

I acknowledge that I have read and understood the University’s rules, requirements, procedures and policy relating to my higher degree research award and to my thesis. I certify that I have complied with the rules, requirements, procedures and policy of the University (as they may be from time to time).

...........................................

Ryan Clark Holding

April, 2014
The aim of this research was to examine the acute effects of implementing a video-based warm-up intervention on performance in a sport-specific agility test. More specifically, the research investigated the ability of a video-based warm-up to provide an acute effect on response time within a novel, ecologically-valid testing protocol. In addition, the differences between implicit and explicit learning strategies used within these videos were compared for their benefits to subsequent performance.

To assess sport-specific reactive performance, a novel testing method was implemented using 3D motion analysis. A defending player was challenged to respond to a live attacking player, as is seen in the performance setting. Response time of the defender was analysed using twenty high speed 3D motion analysis cameras. Thirty junior representative rugby players were recruited as participants for the study and allocated into three experimental groups (implicit, explicit, control) based on performance testing results. Following the completion of five pre-intervention trials of the reactive agility test, participants completed a video-based warm up protocol. Implicit- and explicit-based groups watched video clips of attacking players executing a change-of-direction manoeuvre. The explicit group had key biomechanical indicators of movement direction highlighted whereas the implicit did not. The control group viewed highlights of a televised rugby game. All participants then immediately completed an additional five trials of the reactive agility test. This testing session was repeated a week later to assess the reliability of the test.
Results of a two-way general linear model with repeated measures analysis indicated a significant main effect of testing occasion (pre vs post), but no significant interaction of intervention (three groups: explicit, implicit, control) by testing occasion. Post-hoc analysis with Bonferroni adjustment showed that both the explicit (p = 0.030) and implicit (p = 0.049) video groups significantly improved their response time (relative improvement of 19.1% and 15.7%, respectively) while the control group (p = 0.367) remained stable (relative improvement of 4.6%). Although the within-group post hoc analysis indicated a significant effect, this cannot be accepted with confidence due to the lack of a significant interaction. There was no significant difference between the two experimental groups (explicit and implicit). Furthermore a re-test performed one week apart indicated an acceptable level (ICC = 0.638) of reliability of the testing protocol.

The results of the study may suggest that athletes, who compete in sports challenging anticipation based on interpreting an opponent’s postural cues, may benefit from the use of video-based warm-up strategy.
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* A special thank you to my family. None of this would be possible without their support.
Publications

The following refereed publications have been produced during this research process and are directly associated with this thesis:

Journal Article

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Abbreviations

CODS: Change of Direction Speed
MT: Movement Time
RT: Response Time
Hz: Frames per second
RAT: Reactive Agility Test
IVG: Implicit Video Group
EVG: Explicit Video Group
CG: Control Group
COM: Centre of Mass
Definitions of Terms

Agility
A rapid whole-body movement with change of velocity or direction in response to a stimulus (Sheppard & Young, 2006).

Reaction Time
The interval of time between the onset of a signal (stimulus) and the initiation of a response (Magill, 2007).

Movement Time
The interval of time between the initiation of a movement and the completion of the movement (Magill, 2007).

Response Time
The sum of reaction time and movement time; therefore the time from stimulus onset to the termination of the response.
Chapter 1 - Introduction

1.1 Background of the Research

The nature of a sport is what determines the needs of each individual athlete. The rules and tactics employed govern the physical and mental requirements of its players. Where sports are ‘open’ in nature and involve at least two teams simultaneously competing against one another, the need to outperform an opponent in both the physical and mental components of the sport is imperative. Therefore, training and preparation that elicits the best outcomes specific to the nature of the individual sport, both in the long-term and short-term prior to performance is vital.

Open-type sports are sports that predominantly involve open motor skills. As defined by Magill (2011) these are “skills that a person performs in an environment in which supporting surfaces, objects and/or other people are in motion while the person performs the skill” (p. 10). These skills are often termed “externally paced” as performers of open skills must time the initiation of their movement with an external feature in the environment (e.g. an opponent) (Magill, 2011). This is in contrast to closed skills which are more self-paced within a relatively unchanging environment (Lerner, Ostrow, Yura, & Etzel, 1996).

In these open-type sports (e.g. soccer, basketball, boxing, tennis, rugby), the ability to successfully anticipate an opponent’s movements can be the hallmark of a very successful player (Serpell, Ford & Young, 2010; Sheppard & Young, 2006). The earlier a player can
read and interpret cues from an opponent, the more time they have to formulate and perform a response, therefore increasing the likelihood of success (Farrow et al., 2005).

Training anticipation in the past has been an indirect result of training games and match play. Overtime, this approach improves an individual’s ability to anticipate in their specific sport and this type of training for anticipation may still be the optimal method. However, the development of new technology provides new opportunities for training and enhancing performance.

Testing for reactive ability within sporting contexts has been an area of interest for some researchers. Researchers have noted that the perceptual-cognitive ability of an athlete can serve as a distinguishing factor between successful high performance athletes and their peers (Farrow, Young, & Bruce, 2005; Gabbett & Benton, 2009; Henry, Dawson, Lay, & Young, 2011). Recent research (Engelbrecht, 2011; Farrow & Abernethy, 2002; Farrow, Young, et al., 2005; Gabbett & Abernethy, 2013; Gabbett & Benton, 2009; Henry et al., 2011; Hopwood, Mann, Farrow, & Nielsen, 2011; Serpell, Ford, & Young, 2010; Williams, Ward, & Chapman, 2003) has applied a variety of novel testing mechanisms in order to quantify an athlete’s sport-specific reactive ability. This current study has attempted to build upon these approaches by applying a new method that highly replicates the performance setting.

Recent research in the area of training sport-specific agility has proposed a number of methods via which to improve an athlete’s performance (Hopwood et al., 2011; Serpell, Young, & Ford, 2011). Researchers have used a variety of methods to replicate the performance setting, as to allow athletes to be exposed to sport-specific situations, with the goal of stimulating an improvement in perceptual-cognitive ability. Some of these studies
(Farrow & Abernethy, 2002; Hopwood et al., 2011; Serpell et al., 2011) have been successful in improving their athlete’s perceptual-cognitive ability. The nature of the testing has however made it somewhat unclear as to the benefit to the athlete within the performance setting. Also, the type of learning utilised within the training environment has become a consideration as explicit and implicit strategies have both been implemented with varying results (Farrow & Abernethy, 2002; Hopwood et al., 2011; Serpell et al., 2011). Notwithstanding this, sport science researchers have begun to favour implicit-based strategies within training for a number of reasons (Farrow & Abernethy, 2002; Jackson & Farrow, 2005; Masters, 1992). In order to shed more light on this discussion, this study compared and contrasted the two learning strategies on their ability to provide an acute effect on sport-specific reactive performance.

This study, using a testing design representative of the performance setting, attempted to assess the acute effect of incorporating a video-based warm-up protocol on subsequent anticipation performance. Implicit and explicit learning strategies were implemented within the video-based warm-up protocol to allow the subsequent effects to be used to assess the efficacy of the two strategies.

1.1.1 The Nature of Rugby Football

‘Rugby football’ is an inclusive term used to describe two similar sports: rugby league and rugby union. Both played throughout the world, rugby league and rugby union share many similarities. The rules of play make these sports somewhat different, yet many of the foundations of the game remain identical. Major similarities including not being able to pass the ball forwards, offside rules, and field size ensure that many of the fundamental skills remain interchangeable between the sports to a certain extent. The goal of each team
within rugby football sports remains the same: to advance down the field to the opponent’s end of the field and accrue points by scoring a ‘try’ or kicking goals. The defending team’s goal is to limit the advance of the attacking team by making tackles and forcing possession turnovers. In addition, both sports require its players to demonstrate very similar physical characteristics and qualities, which is evident by numerous professional players achieving the title of ‘dual-international’, a term used to describe individuals that have represented their respective nation in both rugby league and rugby union.

When rugby football players are in possession of the ball, they have three options; pass to a supporting player, kick to gain field position or to run and gain as much ground as possible before being tackled. When running the ball, players may utilise a range of manoeuvres in order to evade the opposition defence. A critical and fundamental attribute for a defensive player is to be able to read and predict accurately what the attacking player is going to do and therefore move accordingly to make the tackle. In this regard, it is imperative that a player displays high levels of sport-specific agility in order to be competitive at a professional level.

The dynamic nature of rugby football as a full contact sport places significant demands on players, both physically and psychologically. As outlined by Meir et al. (2001), professional players display above average levels of strength, power, speed, agility and endurance, coupled with the need to be adept at individual technical and team tactical skills of the game.
1.1.2 Framework for Improving Agility Performance

1.1.2.1 The Definition of Agility

Agility has seldom had a universally-accepted definition within the sport science literature. In response to this problem, Sheppard and Young (2002) completed a review on the topic and proposed a model outlining the components of agility (Figure 1.1). Following the development of this model, numerous studies have compared the agility performance of highly-skilled and novice athletes (Farrow, Young, et al., 2005; Gabbett & Abernethy, 2013). These researchers identified the perceptual-cognitive components of agility as the distinguishing factor of performance between skill levels within these agility tasks, as opposed to the change of direction speed factors. This highlighted the need to focus training studies on the improvement of sport-specific perceptual qualities of athletes.

![Figure 1.1: Components of Agility Performance (Young et al., 2002)](image)
1.1.2.2 Expert Agility Performance

Following on from these studies, and the recognition of the important role that the perceptual-cognitive components of agility play during expert performance, further research has been completed in an attempt to identify the specific abilities that expert performers possess, thus allowing them to exhibit greater perceptual-cognitive abilities within sport-specific agility tasks. Sheppard and Young (2006) presented (adapted from Cox, 2002) the information-processing model that explained how athletes respond to stimuli within the sports performance setting (Figure 1.2).

![Information-processing Model](image)

Figure 1.2: Information-processing Model

Linking the information-processing model to agility performance, Sheppard and Young (2006) summarised Cox (2002) by stating:

> when considering the human information-processing model, a stimulus produces specific mental operations that are based on the individual’s retrieval of stored memory information before initiating a response. The accuracy and speed of this response will be dependent on the previously stored information specific to that situation. (p. 928)
Therefore, athletes with a high perceptual-cognitive ability have a greater ability to utilise stored memories in regard to the specific situation, which in turn allows them to anticipate the actions of opponents.

Ericsson (2000) proposed that high level performers on perceptual-cognitive tasks are able to overcome the limits imposed by basic information processing capacities such as short-term memory and visual reaction time (Williams & Ericsson, 2005). Williams and Ericsson (2005) suggested that experts are able to overcome the temporal constraints common within the sporting context due to developed knowledge structures that allow the anticipation of future actions. This relates to the information-processing model in that developing knowledge structures allows for efficient mental operations in order to quickly respond to a stimulus.

1.1.2.3 Developing Expert Agility Performance

The task for researchers was therefore to determine how these experts develop the sport-specific knowledge structures that allow for improved perceptual-cognitive performance. Williams & Ericsson (2005) posited that:

> the ability to effectively pick up advanced postural cues, to scan the visual display in an appropriate manner, and to orientate attention only to the most pertinent sources of information are due to specific adaptations as a result of practice and experience of the task. (p. 298)

Williams and Grant (1999) stated that “the enhanced cognitive knowledge base which underlies experts’ perceptual skill appears to be primarily developed as a result of sport-specific experience” (p. 196). Therefore, the current theory of expertise within perceptual-cognitive tasks is that athletes develop specific knowledge structures within the specific
context of the sport that allow them to respond faster to a stimulus via increasing their efficiency in recognising the stimulus and determining the appropriate response to be executed. This will therefore allow for the anticipation of future events more efficiently than their novice counterparts. Training studies have documented that anticipation training can result in an improvement of response time in sport-specific tasks (Hopwood et al., 2011; Serpell et al., 2011). It is less clear however, as to how much time is needed to accrue these benefits. Williams (1999) stated:

It may be that perceptual effects accrue almost immediately and that extending practice beyond this initial stage has only limited benefits. Clearly, the law of practice would suggest that improvements are likely to be rapid at first and much slower later as performance plateaus. (p. 213)

How perceptual-cognitive skill adaptation can be facilitated through intervention programs has been debated extensively within the literature. Specifically, the merit of explicit and/or implicit-based learning strategies and the benefit each hold to skill acquisition has been studied (Masters, 1992). Both learning strategies have been endorsed and opposed at various points within the literature.

Anderson (1982) advocated explicit instruction as he proposed that knowledge is initially stored in a declarative form and interpreted with general procedures (in the form of “if-then” statements). These procedures however, are slow and place heavy demand on the working memory, although they offer adaptability and allow declarative knowledge to impact on behaviour without relinquishing control (Anderson, 1982). It has also been stated by Smeeton et al. (2005) that: “the prescriptive nature of explicit instruction is thought to accelerate early learning and the formation of specific productions such that
time spent searching for relevant information is reduced” (p. 98-99). In addition, the declarative knowledge gained through explicit instruction has been thought to provide a structured framework for subsequent knowledge development (Chase & Ericsson, 1982). Implicit learning strategies have also been heavily promoted amongst sport psychology researchers. It has been shown that performance improvements can be made on complex tasks without knowledge of the rules that control the system (Berry & Broadbent, 1984). In addition, researchers have stated that explicitly directing participants to the rules of performance may in fact be detrimental to performance (Smeeton, Hodges, Williams, & Ward, 2005).

Magill and Clark (1997) offered an additional proposition when judging the efficacy of differing learning strategies on adaptation to perceptual-cognitive tasks. They outlined that implicit strategies may be beneficial when the relationship between the stimulus and response was not totally predictable, while explicit strategies may be of benefit when there is limited uncertainty (Magill & Clarke, 1997). Smeeton et al. (2005) therefore concluded that: “In real-world tasks where anticipation may not be totally predictable from one situation to the next, less prescriptive types of instruction might be preferable in comparison to explicit rule-based methods” (p. 99).

Recent training studies have focused on developing novel methods of improving an athlete’s sport specific knowledge base as the method of improving agility. Training studies have employed video projections of opposition players performing movements, which offer the training participant the opportunity to be exposed to the advanced postural cues in order to anticipate future movement. The theoretical basis of this technique is that exposing athletes to various sport-specific situations (with a performance setting
perspective), allows the athlete to develop a knowledge base of the associations between specific advance postural cues and the resultant movement outcome. Results have shown that these methods can be successful in improving the perceptual-cognitive performance of these athletes (Hopwood et al., 2011; Serpell et al., 2011). Whether an improvement can be produced on an acute basis within a sport-specific open agility test is less clear.

Using the above framework for improving perceptual-cognitive performance within agility tasks, the current study aims to determine whether an athlete’s sport-specific knowledge structure can be increased on an acute basis using a video-based intervention. In addition, the use of the two contrasting learning strategies will be implemented in an attempt to provide further clarity regarding the efficacy of each for developing the perceptual-cognitive components of agility.

1.2 Significance of the Research

Athletes and strength and conditioning coaches are always seeking to improve performance. Training methodologies are created specifically to maximise an athlete’s performance capacity specific to their sport. Through the use of novel training and testing methods, it is posited that this research could provide a further dimension to performance training.

This study will be the first to assess the acute benefits of incorporating a video-based perceptual-cognitive training aspect into a sporting warm-up. This study may provide valuable information as to whether agility performance in a sport specific setting can be improved with the use of video technology. In addition, an ongoing topic within the skill acquisition literature is the efficacy of different learning strategies employed within training. Implicit and explicit based strategies have been both endorsed and opposed at
different stages within the literature. This study compares and contrasts the effects of each on their ability to facilitate an acute effect to response time within an agility task. The results may therefore add a new dimension to the discussion on the value of each strategy, as they relate to anticipation training.

Coaches are often limited in the training methods used due to equipment, time and facility constraints. Due to the athlete’s need to physically prepare for performance, coaches often have limited time prior to competition. In addition, specific facilities available for warm-up to athletes may change on a weekly basis. The results of this study may provide the basis for sport-specific anticipation training to be completed individually in resting time prior to performance (or on route to the game facility) on portable devices (e.g. mobile phones, iPads, etc). This would therefore allow the coaches to provide the athletes with an acute benefit to performance without compromising the usual performance preparation routine.

1.3 Statement of the Problem

Agility training studies have begun to focus on the perceptual-cognitive component of agility and have utilised video technology in their methodology (Serpell, Ford & Young, 2010; Farrow et al., 2005). Many of these training studies using video-based training protocols to improve anticipation have not measured the athlete’s improvement rate. These studies have primarily measured reactive performance improvement following a 4-6 week intervention period. Therefore, the acute benefits of video-based reactive training are not evident within the literature. Further research is therefore required in this area. In addition, much of the research has employed testing batteries that attempt to replicate the performance setting through video-technology. This study attempts to improve acute
agility performance by testing within a highly representative setting (i.e. ecologically relevant).

The type of learning strategy used within these studies to improve sport-specific agility has also been inconclusive. The positives and negatives for both strategies have been highlighted (Masters, 1992; Williams & Grant, 1999) and it is therefore somewhat unclear as to the ideal approach. This study therefore, compared the two strategies in an attempt to provide further clarity on this issue.

1.4 Aims of the Research

The current study was proposed to investigate the acute effects of a video-based warm-up on the anticipation and agility skill of junior rugby football players. Specifically, the study was designed to:

1. Assess the reliability of a 3D motion analysis system as a new method for quantifying response time.

2. Determine the acute effects of a video-based warm-up on performance during a rugby football specific reactive agility test (RAT).

3. Determine the difference between implicit and explicit video-based warm-ups in relation to their benefit on performance in a rugby football-based RAT.

1.5 Research Hypotheses

1. The sport-specific performance test, measured by a 3D motion analysis system, has an acceptable level of reliability.
2. Performance on a reactive agility test, as determined by response time, will be significantly improved after the completion of a video-based warm-up in comparison with the control group (Research hypothesis).

3. There will be no significant difference in the level of response time improvement on the reactive agility test between the implicit and explicit video-based warm-up groups (Null hypothesis).

1.6 Limitations of the Research

Previous studies into agility performance have tested individual’s response/decision time in response to a video-based stimulus. The current research design utilised a ‘1-v-1’ sport-specific test in which the participant is challenged to respond to a real-life stimulus. This design has been utilised as it is believed to be more representative of the performance setting. This design however did present possible study limitations. The nature of the test, being an open 1-v-1 test, may provide possible inconsistencies in stimuli as different subjects will move at different speeds and in differing styles. This however is the nature of rugby football in that different players display different movement qualities thus challenging the defender to use anticipation to successfully complete a tackle.

A point of difference between the current study and previous studies on agility is that this study did not measure the total test time (time to reach a set point). This study only quantified the response time within the agility task and therefore only assessed the perceptual-cognitive elements of agility. Within the sporting setting, although speed is a crucial component of performance, the overall time from two specific points may not be as vital as the ability to arrive at a specific point at an effective time point and in an appropriate position to carry out an effective skilled movement based on the game action.
This study was primarily interested in whether a video-based warm-up could elicit a benefit for the perceptual-cognitive components of agility and therefore a total time was not deemed necessary.

A greater understanding of the value of video-based warm-up protocols may be ascertained with the use of players from differing levels of experience/skill. Whilst it may be more favourable to use players from different performance groups, i.e. amateur, professional, elite, the location of this university made this difficult. As a result only junior representative players from the local competition were used as participants.

The current study made an attempt to assess a video-based warm-up for its acute benefit to agility performance within junior rugby football. The results and implications garnered from this study were therefore limited to this specific sporting context.
Chapter 2 - Literature Review

2.1 Agility

Elite performers in most sports, and in particular rugby football, need to excel in many facets of performance in order to be successful. One of the key components of a successful athlete is agility. It has been stated by Verstergen and Marcello (2001) that: “agility permits an athlete to react to a stimulus, start quickly and efficiently, move in the correct direction, and be ready to change direction or stop quickly to make a play in a fast, smooth, and repeatable manner” (p.140-141).

Throughout the research literature however, agility appears to have been widely misunderstood and poorly defined. In earlier research, agility was defined as simply ‘the ability to change direction rapidly’ (Bloomfield, Ackland & Elliot, 1994; Clarke, 1959; Matthews, 1973) or alternatively ‘the ability to change direction rapidly and accurately’ (Barrow & McGee, 1971; Johnson & Nelson, 1969). These earlier definitions only described the physical aspects of agility and testing, and training studies reflected these definitions. Studies with a focus on improving or testing an athlete’s level of agility did so by employing simple movement drills with pre-planned changes-of-direction. Examples of these include the ‘T-test’ (Bloomfield, Polman, O'Donoghue, & McNaughton, 2007; Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000; Semenick, 1990) ‘Illinois Agility Run’, ‘505-test’ (Draper & Lancaster, 1985) and the L-run (Meir, Newton, Curtis, Fardell, & Butler, 2001).
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The perceptual-cognitive component of agility was first highlighted when Chelladurai (1976) noted that no previous definitions took into account the reactive nature of many sports. As was stated in Chelladurai (1977), “these definitions do not take into account the variations in the stimulus field that trigger the agile performance” (p. 1319). Chelladurai (1976) expanded the definition of agility into four classifications: simple, temporal, spatial and universal. The definitions of each are presented in Table 2.1.

Table 2.1: Classifications of Agility (Chelladurai, 1976)

<table>
<thead>
<tr>
<th>Agility Classification</th>
<th>Definition Applied Sporting Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>No spatial or temporal uncertainty Gymnastics floor routine: pre-planned activity, initiated when the athlete desires, with movements that the athlete has pre-planned</td>
</tr>
<tr>
<td>Temporal</td>
<td>Temporal uncertainty, but movement is pre-planned 100m sprint start: pre-planned activity, initiated in response to a stimulus (starting gun) wherein there is no certainty as to exactly when the gun will fire</td>
</tr>
<tr>
<td>Spatial</td>
<td>Spatial uncertainty, but timing of movement is pre-planned Tennis serve receive: the umpire determines a narrow window in which the server must serve the ball, however the receiver has no certainty on where the service will be directed</td>
</tr>
<tr>
<td>Universal</td>
<td>Spatial and temporal uncertainty Football: during attacking and defensive situations, the athlete has no certainty on when and where the opposition players will move to and therefore relies heavily on reactive abilities</td>
</tr>
</tbody>
</table>
Chelladurai’s (1976) research therefore highlighted that movement tasks in different sporting situations require diverse levels of cognitive involvement in relation to where, when and how to move.

Since Chelladurai’s (1976) research, additional studies have been conducted in order to define agility. Extending Chelladurai’s study, Cox (2002) described agility tasks as being of either an open or closed nature. Cox (2002) described open agility skills as those that require athletes to respond to sensory stimuli, and where the response is not automated or rehearsed (as cited in Sheppard and Young, 2006). Pre-planned skills, where no response to a stimulus is required, are referred to as closed skills. Young et al. (2002) argued that simple or closed agility movements should not be referred to as agility tasks. This research proposed the term “change-of-direction speed”, which encompassed all sprinting drills with a change of direction. Their research proposed that change of direction speed was a component of agility and could also describe closed agility tasks where no cognitive involvement was required (Young, James, & Montgomery, 2002).

More recently, Sheppard and Young (2006), in summarising previous research into agility developed a new definition of agility, which described it as: “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (p. 922). This definition therefore addresses both the perceptual-cognitive component of agility in addition to the physical (changes of direction and/or velocity) components. This definition also highlights that directional changes are not necessary for the skill to be termed an agility task, since not all responses to stimuli in sport require the athlete to change direction. Sheppard and Young (2006) also developed their own criteria for the
classification of skills as agility tasks, based on their definition and suitability. These are presented in Table 2.2.

Table 2.2: Criteria for the classification of agility (Sheppard & Young, 2006)

<table>
<thead>
<tr>
<th>Agility</th>
<th>Other physical or cognitive skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Must involve initiation of body movement and/or change of direction, or rapid acceleration or deceleration.</td>
<td>o Entirely pre-planned skills such as shot-put classified by their skill function rather than included as a type of agility</td>
</tr>
<tr>
<td>o Must involve whole-body movement</td>
<td>o Running with directional changes classified as a change of direction speed (CODS) rather than agility or quickness</td>
</tr>
<tr>
<td>o Involves considerable uncertainty, whether spatial or temporal</td>
<td>o Closed skills that may require a response to a stimulus [e.g. the sprint start in response to the starter’s pistol is pre-planned (closed) and therefore not agility]</td>
</tr>
<tr>
<td>o Open skills only</td>
<td></td>
</tr>
<tr>
<td>o Involves a physical and cognitive component, such as recognition of a stimulus, reaction, or execution of a physical response</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Components of Agility Performance

As efforts have been made to produce a unified and all-encompassing definition of agility, many models of agility performance highlighting the components of the skill have been produced. Young et al. (2002) produced a model of agility highlighting the key components of agility performance (Figure 1.1).

Within the model of agility proposed by Young et al. (2002), two broad components of agility were specified. These components were ‘change of direction speed’ and also ‘perceptual and decision-making factors’. The change of direction speed component relates
to the physical demands of agility that allows the athlete to move fast and efficiently. The perceptual and decision making component deals with the ability of the athlete to recognise and effectively interpret sport-specific cues from their field of vision in order to make fast, accurate decisions regarding when and how to move.

2.2.1 Change of Direction Speed Factors
The change of direction speed component of agility performance addresses the physical nature of agility. Young et al. (2002) highlighted four key areas that impact upon change of direction speed and in turn agility performance. These factors include technique, straight sprinting speed, leg muscle qualities and anthropometry.

2.2.1.1 Technique
The running technique employed by athletes is primarily governed by the sport setting in which they are competing. The technique employed by athletes competing in open type sports including rugby, Australian rules football, soccer, etc., differs markedly from the technique used by track sprinters.

Both open-type sport athletes and track sprinters utilise a pronounced forward lean and a low centre of gravity during acceleration (Mann, 1981; Sayers, 2000), however field athletes are required to maintain their visual focus on the playing environment whereas track athletes are taught to keep the visual focus low (Francis, 1997). Additionally, because field sport athletes are typically required to display speed over shorter and more varied distances than track athletes, they are required to accelerate and reach maximal speed in a much shorter amount of time. Track athletes by comparison extend their acceleration time in order to reach top speed at a predetermined point in the race thus suffering less speed reduction in the final stages (Sheppard & Young, 2006). Sayers (2000)
proposed that due to the unpredictable nature of open-type sports, which results in frequent changes of direction, field-sport athletes should adopt a running technique with a focus on a low centre of gravity, greater forward lean and shorter stride length. A low centre of gravity is required to change direction and therefore athletes running with a high centre of gravity are slowed by the time needed to drop their centre of gravity to the required level to change direction (Sayers, 2000).

Rugby football has its own set of variables that impact on the running style utilised during the match. As players only have less than ten metres between themselves and the defensive line, players need to rapidly accelerate and brace for potential collisions. A low centre of gravity is required as a result of the need to rapidly change direction in order to evade the defensive players. Through match analysis, running durations were recorded for different playing positions in professional rugby league (Gabbett, 2012). It was found that ‘hit-up forwards’ had a mean sprint distance of only 6-10 metres and of all players 67% of sprints were less than 20m in distance. Additionally, 48% of total sprints in the game included contact with an opposition player. These statistics show that rugby football players must adopt a different technique to track sprinters in order to accelerate to top speed as quickly as possible and also change direction efficiently in order to avoid defenders.

2.2.1.2 Straight Sprinting Speed

Perhaps somewhat counter intuitively, research shows that straight sprinting speed does not correlate highly with performance in a change of direction speed test. While using the Illinois shuttle run as a test of agility, Draper and Lancaster (1985) found weak correlations with a straight 20m sprint. Young et al. (1996) also found no correlation between linear sprinting speed performance and change of direction speed, specific to
Australian Rules football (Young, Hawken, & McDonald, 1996). This result was also found when sprinting and change of direction speed tests were implemented using professional rugby league players (Baker & Nance, 1999). This data has given rise to linear sprinting speed and change-of-direction speed being deemed separate physical qualities, which need to be tested and trained independently of one another.

2.2.1.3 Leg Muscle Qualities

It has been shown in previous research that a moderate to strong correlation exists between increased leg power/strength and straight sprinting speed (Baker & Nance, 1999). This has led some strength and conditioning coaches to assume that a similar crossover effect occurs when training for change of direction speed. However, in much the same way that sprinting performance does not generally carry-over to CODS performance, research does not generally support this notion. For example, Young et al. (1996) found a weak correlation between a weighted countermovement jump and a CODS drill with 90° directional turns. It has also been reported in the literature that the L-run, a twenty metre CODS drill with three directional changes, does not strongly correlate with validated lower body power measurements such as the vertical jump and the standing broad jump (Webb & Lander, 1983). Keiner, Sander, Wirth & Schmidtbleicher (2013) however found that additional strength training over a two year period significantly affected CODS performance. Participants aged between thirteen and eighteen years at the beginning of the study were placed in either a control group (who only completed routine soccer training) or the experiment group (who completed an additional strength training program in addition to the soccer training). The researchers reported a significant correlation between relative strength and change of direction speed following the two year intervention (Keiner, Sander, Wirth, & Schmidtbleicher, 2013).
Young and Farrow (2006) stated that highlighting the muscle qualities of the leg may be an oversimplification of the system. It was stated that:

- rapid extension of the leg might produce high forces laterally to the ground,
- but the ground reaction forces will not be effective for propulsion of the centre of gravity if the trunk or core of the body absorbs rather than transmits the forces. This provides a rationale for developing core stability as well as for viewing COD speed as a function of an entire kinetic chain, rather than just the function of legs. (p.26)

The majority of the research has investigated whether there is a correlation between strength/power performance of the lower limb and increased COD performance. Young et al. (2002) studied reactive strength imbalances between the lower limbs and their relationship to CODS imbalances between directions (i.e. the time taken to step left or right). It was found that imbalances between the limbs can contribute to a difference between movement directions in terms of time. In opposition to much of the aforementioned studies, Castillo-Rodriguez et al. (2012) found a correlation between countermovement jumps, drop jumps and CODS. They found that single-leg countermovement jumps were accurate predictors of direction dominance when turning. On this basis they concluded that these jumps should be included in any CODS training program.

Henry et al. (2013) noted that agility tasks in most sports are characterised by movements involving only one leg, under high stretch-shortening cycle loads (reactive strength) (Henry, Dawson, Lay, & Young, 2013). The authors therefore hypothesised that perhaps unilateral drop jumps could be a predictor of agility performance, as opposed to bilateral exercises including the back squat and squat jumps, which have been shown to have a
weak correlation to CODS. Much like the weak correlation between leg strength qualities and CODS, the researchers found that there was a weak correlation between reactive strength (via the use of unilateral drop jumps) and agility (Henry et al., 2013).

The importance of leg muscle qualities to CODS performance may not be reflected in agility tasks requiring a response to stimuli. Sheppard et al. (2006) researched the correlations between straight sprinting speed, CODS and performance on an agility task and found a moderate ($r=0.74$) correlation between straight sprinting speed and CODS. A weak ($r=0.34$) correlation however, was found between straight sprinting speed and agility, highlighting the importance of the perceptual-cognitive demand of the agility task. Therefore, while the training of leg muscle qualities for closed CODS performance may be beneficial, this may not be reflected in the sports performance setting where athletes are reacting to stimuli in an open environment.

2.2.1.4 Anthropometry

So far in the literature, comprehensive investigations into the relationships between anthropometric factors and change of direction speed have yet to be conducted. It is hypothesised however that variables such as body fat and body segment length may have an effect on CODS performance (Sheppard & Young, 2006). In theory, when comparing two athletes of the same total body mass with different body fat percentages, the leaner athlete will have more lean mass available for speed production. Conversely, the less lean athlete will have to produce more force per unit of lean mass to produce a change in velocity/direction (Enoka, 2002). Correlations between low body fat and increased COD performance has been shown within testing studies specific to rugby league, rugby union
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and football (Gabbett, 2002; Meir et al., 2001; Reilly, Williams, Nevill, & Franks, 2000). The direct relationship between the two variables however remains somewhat unclear.

An athlete’s height has also been suggested to have an impact on CODS performance (Sheppard & Young, 2006). It is hypothesised that a shorter athlete may have a lower centre of gravity and therefore be able to apply more horizontal force more rapidly than a taller athlete with a higher centre of gravity. This may be a result of requiring less time to lower their centre of gravity in order to laterally change direction. Further research is required in order to assess this theory.

2.2.2 Perceptual and Decision-Making Factors

The second component of agility deals with the cognitive involvement of the skill. How quickly an athlete can pick up specific cues and respond accordingly in a fast and accurate manner can have a great effect on speed in a sport-specific setting. Young’s (2006) model of agility highlights anticipation, visual scanning / visual searching, and knowledge of situations and pattern recognition as the key components of the perceptual and decision-making component of agility.

2.2.2.1 Anticipation

The ability to anticipate is crucial to performance in sport, as well as to performance in other fields, such as military combat, law enforcement and routine daily tasks (Williams, Ford, Eccles, & Ward, 2011). Specific to sports performance, the ability to anticipate an opponent’s actions based upon partial or advance sources of information is essential because of the time constraints placed on the performer, particularly in fast ball sports (Abernethy, 1987). In open-type sports such as rugby football and tennis, which require its athletes to respond to an opposition player’s movements in order to make an effective
tackle or service return, anticipation is extremely important for success (Farrow et al., 2005; Serpell et al., 2010). These situations are often performed under severe temporal constraint, and therefore the difference between successfully completing the task (e.g. completing a tackle or returning serve) and failing to complete the task (e.g. being evaded by the attacker or not returning serve) is often miniscule. This therefore highlights the need to initiate a response as early as possible. To do this, it is necessary for performers to adapt to the unique constraints of the task by acquiring knowledge structures and cognitive processes that allow them to anticipate, which in turn allows athletes additional time to formulate and execute an appropriate response (Williams et al., 2011).

Williams (2009) presented an alternate framework that highlighted the key perceptual-cognitive skills underlying anticipation in sport. This framework (Figure 2.1) also attempted to illustrate how these perceptual-cognitive skills interact during performance under different constraints.

![Interactive relationship between perceptual cognitive skills and constraints (Williams, 2009)](image)
As outlined by Williams (2009), the key perceptual-decision making skills underlying anticipation include:

(a) the ability to pick up advance information from an opponent’s postural orientation, (b) a capacity to identify familiar patterns of play or sequences within dynamic team sports, (c) greater efficiency and effectiveness in moving the eyes around the display in an effort to extract information from relevant display areas, and (d) the capability to accurately predict the likely choice options open to an opponent at any given moment. (p.74)

The perceptual decision making skill of being able to pick up advance information from an opponent’s postural orientation, as outlined by Williams (2009), has been studied in depth within recent literature. This skill has been termed ‘advance cue utilisation’.

2.2.2.2 Advance Cue Utilisation

‘Advance cue utilisation’ has been defined a number of times in previous research. Early in the literature, Poulton (1957) defined ‘perceptual anticipation’ as the ability to make predictions based upon partial or advance sources of information. Abernethy (1987) extended this research to define advance cue utilisation as an athlete’s ability to make accurate predictions based on contextual information available early in an action sequence. Williams (2000) referred to advance cue utilisation as “a player’s ability to make accurate predictions based on information arising from an opponent’s posture and bodily orientation” (p.739). Using this definition, advance cue utilisation is crucial for rugby football in that being able to anticipate an attacker’s movements based on subtle body postural alterations gives a defender a much greater chance of successfully completing a tackle; or in the case of the attacker, the ability to “wrong-foot” and beat the defender.
Advance cue utilisation has been studied using a number of techniques within the literature. These diverse techniques can be categorised into laboratory-based and field-based approaches (Williams & Grant, 1999). Laboratory-based approaches have seen the use of film to simulate performance from an athlete’s point-of-view. Within laboratory-based studies of advance cue utilisation, the most frequently used techniques for research have been the ‘film occlusion’ approach, where the films are edited in relation to duration and nature by the researcher, and the ‘reaction time’ approach, where the films are unedited and the viewing time of the film display is under the athlete’s control (Williams & Grant, 1999).

Many recent studies in the area of understanding the way experts utilise anticipation within sport have made use of the film-occlusion technique (Farrow, Abernethy, & Jackson, 2005; Huys, Cañal-Bruland, Hagemann, & Williams, 2009; Williams & Grant, 1999). There are two methods of occlusion that are used within these studies: temporal and event. Temporal occlusion involves the selective editing of films by the length of viewing time, therefore varying the extent of anticipatory cues available to the athlete. For example, occluding film of an opposition tennis player serving at the time of ball contact forces the responding athlete to make a judgement of service direction without the use of ball flight information.

Temporal occlusion was the basis of a study by Jones and Miles (1978) that studied the differences in anticipation ability between tennis players and non-tennis players responding to film of tennis serves. Three conditions of temporal occlusion were used: 336ms after ball contact, 126ms after ball contact and 42ms prior to ball contact. The researchers found that within the trials where the film was occluded earlier (i.e. 126ms
after contact and 42ms prior to ball contact), the experienced tennis players were significantly more accurate at determining service direction than the novice players (Jones & Miles, 1978). Salmela and Fiorito (1979) replicated this study design in the context of ice hockey. Films were occluded at 500ms, 333ms or 166ms prior to the attacker striking the puck for a shot on goal. Participants verbally responded to the clip by electing which corner of the goal the puck was directed towards. The results showed that the ice-hockey goalkeepers were successfully able to anticipate shot direction by utilising advanced postural information (Salmela & Fiorito, 1979). Additionally, using a Likert scale, the researchers assessed the confidence levels of the athlete’s decision making. After anticipating shot direction, participants indicated their confidence level with their decision. Confidence levels dropped as the occlusion time increased; however levels were still high at the 333ms occlusion prior to puck strike. It has been argued more recently that experts are more confident in their decisions than novice athletes (Chamberlain & Coelho, 1993). As a result, novice athletes tend to wait for more anticipatory cues to become apparent before making a judgement, in contrast to expert athletes who are more confident in making correct judgments based on partial sources of information (Chamberlain & Coelho, 1993).

Salmela and Fiorito (1979) categorised the responses by the ice-hockey goalkeepers to the film into four areas: i) total success (when the correct corner was selected); ii) horizontal success (when the participant selected the correct side but incorrect height); iii) vertical success (where the participant selected the correct height but incorrect side); iv) and no success (where the participant selected the wrong side and height of the shot). It was determined that the goalkeepers were more adept at predicting shot side rather than shot height when using pre-contact anticipatory cues from the opponent’s postural orientation.
This result was mirrored by Williams and Burwitz (1993) who studied anticipation abilities of soccer goalkeepers during penalty kicks. The goalkeepers viewed film of the opposition player taking the penalty kick that was occluded at either 120ms prior to ball strike, 40ms prior to ball strike or 40ms after ball strike. The results reinforced previous studies results that found that the expert performers significantly outperformed the novice athletes to a greater degree the earlier the film was occluded (Williams & Burwitz, 1993). This result again highlighted the expert’s greater ability to make use of advance cues to formulate a response. Williams and Burwitz (1993) also found that the participants were much more successful in using advanced cues from the opponent’s body orientation to anticipate shot direction (left/right) as opposed to shot height (high/low). It has been suggested that this result may be attributed to the use of two-dimensional film use as the participants viewing of the environment (Williams, Davids, & Williams, 1999). As stated by Williams et al. (1999) “the loss of dimensionality may make it difficult for subjects to accurately estimate depth, or alternatively, it may cause them to alter their habitual performance strategy” (p.108).

More recently, Jackson, Warren and Abernethy (2006) found, using the temporal occlusion approach, that experts are more proficient at anticipating opponent movement direction in 1-v-1 rugby situations. This study extended the literature by determining that experts are more adept at predicting opposition player movement even when the opposition player is utilising deceptive movements aimed at confusing the participant. This highlights an additional characteristic of expert anticipatory skill, which is the ability to detect and respond appropriately to advance deceptive visual information (Jackson, Warren, & Abernethy, 2006).
As opposed to temporal occlusion, event occlusion involves presenting the participant with a consistent time course of event across trials with the selective occlusion of specific cue sources for the duration of the trial (Williams et al., 1999). Therefore, using the event occlusion technique, specific sources of information from the opponent that may aid in anticipation are occluded from the participant’s view. This allows the importance of specific cue sources to be assessed for their importance in the anticipation process.

Abernethy and Russell (1987) utilised the event occlusion technique to study the importance of different cue sources to anticipation ability in expert and novice badminton players. The film featured an opposition player performing a range of different strokes. Each trial was occluded at the point of impact. Different anticipatory cue sources were obstructed from view during the film including; the racquet and arm, racquet only, lower body, face and body, and a control condition. The authors hypothesised that if a specific source of anticipatory information was hidden from the participant, this would result in a decrement in performance in comparison to the control condition where an irrelevant cue was masked. The results showed that occluding the participant’s view of the racquet and the arm holding the racquet had a greater decrement on anticipation ability than the other cue sources and it could therefore be assumed that this source of information makes an important contribution to anticipation performance in badminton (Abernethy & Russell, 1987).

More recently, Jackson and Mogan (2007) utilised event occlusion to study the anticipatory strategies of skilled, recreational and novice tennis players. Participants viewed films of an opponent executing a serve from the returner’s point-of-view. Each trial was edited to remove a potential source of information for the returner to predict
service direction. Occluded sources of information included: the ball, arm and racquet, lower body (hips legs and feet), or whole body (everything except server’s head and the ball). A control condition was also used where no occlusion was included. Results indicated that occlusion of the ball was the most damaging to skilled players anticipation ability, in addition to occlusion of the arm and racquet. Occlusion of postural information did not have the same detriment on performance as ball information. It was postulated by the authors that vision of ball toss trajectory in relation to a single reference point was adequate in allowing skilled players to judge service direction (Jackson & Mogan, 2007). A similar study focusing on tennis serving anticipation was recently conducted with the researchers suggesting that high-skilled athletes rely more upon a ‘global’ information pick-up strategy, as opposed to novice athletes who may be more reliant upon ‘local’ anticipatory cue sources (Huys, Cañal-Bruland, Hagemann, Beek, et al., 2009). Williams (2009) echoed this notion as he stated:

It appears that skilled performers rely on a more ‘global’ rather than ‘local’ perceptual strategy when perceiving the actions of others. Skilled performers are able to extract relevant information from several areas simultaneously, implying a degree of redundancy or flexibility in the perceptual strategy employed. A more global perceptual strategy may make experts less prone to attempts by opponents to deceive or disguise their intentions. (p.433)

Applying the above to rugby football, it could be hypothesised that elite performers would be able to utilise a range of simultaneous postural cues from the opponent including hip, shoulder and foot position in order to anticipate movement. However, a less skilled player who may only be able to focus on the foot placement (i.e. a single cue), maybe more
susceptible to “feints” (movements intended to deceive a defender) and therefore be more likely to miss the tackle. This hypothesis has been proven when testing agility in rugby league. Using video projections of opposition players running towards the participant and changing direction, high-level players were shown to react faster than low-level players, indicating that the higher skilled athletes were able to utilise advance cue utilisation, and therefore read postural stimuli more efficiently than lower skilled players (Gabbett & Benton, 2009).

Another approach used to study advance cue utilisation is the ‘reaction time paradigm’. In contrast to the film occlusion technique, where the films are edited in relation to duration and nature by the researcher, the reaction time paradigm does not involve any editing of the film displayed. The length of time available to view the display is under subject control and is allowed to covary with response accuracy. In this technique, participants are able to view the film until they have extracted the information necessary to make an anticipatory judgment. The length of time that the participant views the film, prior to making an anticipatory judgement, may therefore vary between skill levels.

Abernethy and Russell (1984) implemented the reaction time paradigm in their research into advance cue utilisation amongst skilled cricket batsmen. Participants, who were in the position of the batsmen, viewed unedited films of the bowler’s run-up and delivery action. The results showed that when comparing skilled batsmen and less skilled batsmen, the skilled group of participants made more accurate decisions in terms of shot selection and these decisions were made in a shorter timeframe, thus the skilled group were able to extract information from the bowler faster and therefore were more efficient at anticipating bowling direction (Abernethy & Russell, 1984).
In a baseball specific study, Paull and Glencross (1997) used films of pitchers throwing, filmed from the batsman’s point-of-view. Using the reaction time paradigm, skilled and novice baseball batsmen were assessed on their ability to predict pitch direction. It was determined that the skilled batsmen made more accurate decisions in addition to a faster response time (Paull & Glencross, 1997). Williams and Davids (1998) assessed experienced and less experienced soccer players and their anticipation ability in a 3-on-3 situation. Participants watched film of match play lasting 6 seconds, and had to move in response to where they thought the opposition were going to play the ball (either left, right, over their head, or dribble the ball towards them). The researchers found that although the experienced players had significantly faster reaction times, there was no significant difference in response accuracy between the groups.

An additional technique in the study of advance cue utilisation is the use of point-light displays. Originally used by Johansson (1973) to study the perception of human motion, these displays capture the motions of major joint centres of the human body and display them as points of light on a black background (Williams & Ward, 2007). Cutting and Proffitt (1982) explained that the benefit of the point-light displays is that they remove background and contextual cue information which allows movement information to be presented in its simplest form. As stated in Williams and Ward (2007), “the argument is that performers determine an opponent’s intentions based on their perception of the relative motion between specific bodily features, rather than via the extraction of information from more superficial features or an isolated area or cue” (p.205).

Abernethy et al. (2001) compared the ability of expert and novice squash players to make anticipation judgments based on advance cues garnered from the opponent’s body
kinematics. This information was conveyed using a temporal occlusion paradigm in addition to a point-light display technique. Experts were shown to outperform the novice athletes under both conditions. In addition, the same time windows that allowed for anticipation judgments under the occlusion technique were also seen in the point-light display condition. As the authors suggested, this shows that experts' perceptual-cognitive advantage is directly related to their superior pick-up of essential kinematic information (Abernethy, Gill, Parks, & Packer, 2001).

Although these laboratory approaches to studying advance cue utilisation, including film occlusion and the reaction time paradigm, have aided in the understanding of anticipation in sport, they have been criticised for a number of reasons (Williams et al., 1999). Researchers have firstly highlighted how the film displays used within research often do not fully emulate the information provided to athletes within the performance setting. This is seen in that film displays are often smaller in size to the performance setting. Additionally, the use of film has resulted in the loss of dimensionality, which may adversely affect participant ability to quickly and accurately respond to stimuli. It has also been shown in research that the loss of auditory information has a detrimental effect on performance (Takeuchi, 1993). Takeuchi (1993) studied tennis players’ performance with and without earplugs, to eliminate information extracted via auditory senses. The loss of auditory information resulted in players losing more games overall. Additionally, player’s return-of-serve ability was lower with the earplugs whilst serving performance was unaffected. It was therefore suggested that players use multisensory information in an adaptive manner during performance (Takeuchi, 1993).
Williams (1999) highlighted additional problems within previous studies using film occlusion. First, the use of a single performer in creating films for participants viewing may create an unrealistic stimulus due to possible idiosyncrasies. These traits of the performer may make anticipation easier or harder for the participant. Secondly, film occlusion techniques require the experimenter to have a preconceived idea regarding what cues are important for anticipation ability within the specific sporting context. This may result in important cues being incorrectly eliminated from the start, obviously hindering anticipation. Also, evidence suggests that expert performers make use of a more ‘global’ cue pick-up strategy, where they interpret multiple cues simultaneously rather than relying on one specific element (Williams, 2009). Therefore the event occlusion technique may not provide a realistic stimulus for the participant.

Also, as opposed to reaction time paradigms, film occlusion studies, for the most part, do not require an immediate response to the stimulus. As it has been stated that visual information is restored in short-term memory for some time following stimulus occlusion (Sperling, 1963), it is likely that participants are still processing and interpreting information to make an anticipatory judgement following the occlusion of the display. This is unrepresentative of the performance setting where athletes are required to make these decisions under severe temporal constraint (Abernethy, 1987). In this regard, the reaction time paradigm is more beneficial to measuring anticipation ability in sport, as it requires the same instant processing and response mechanisms that are employed within the performance setting.

A final key problem with the majority of previous laboratory-based studies is that they do not include contextual information about the situation. Within the performance setting,
athlete’s decisions are shaped by their knowledge of the environment (e.g. previous action, opponent preferences) and of the situation (e.g. score of the game, amount of playing time left in the game) (McPherson, 1993). It has been shown that decision-making of baseball batsmen is significantly improved when they are aware of this key contextual information (Paull & Glencross, 1997). Using strategic contextual information of the game situation, performers decreased decision time and reduced prediction errors of baseball pitch direction.

In contrast to previously discussed laboratory-based approaches to studying advance cue utilisation, field-based approaches measure performance directly using varying techniques. These include ‘high-speed film analysis’ and ‘vision occlusion’ techniques and may be of greater ecological validity due to the nature of the testing (Williams et al., 1999). High-speed video analysis was first used in a study on anticipatory ability in squash (Howarth, Walsh, Abernethy, & Snyder, 1984). The researchers filmed rallies of squash matches between two high-skill players and two low-skill players with a high-speed camera (100 frames/second) situated above the court. An anticipatory movement was recorded when the athlete made a definitive movement in the direction appropriate to intercept the ball. Results from film analysis showed that the high-skilled players made an anticipatory movement on average 112.5ms after the opponent struck the ball as opposed to 362.5ms for the low-skill group. Viewing time was estimated to end 200ms prior to the anticipatory movement based on research into visual latency time over which visual based corrections could be made (McLeod, 1987). Therefore, viewing time was estimated at -87.5ms for the high skill athletes and 163ms for the low-skill athletes. The negative viewing time for the high-skill athletes suggest that they base their anticipatory movements on advance visual cues gathered prior to the opponent striking the ball. This is opposed to the low-skill
athletes who, with a positive viewing time, must use information post ball contact to make an accurate anticipatory decision. This study therefore highlights the ability of high-skill athletes to pick up and interpret advance sources of information used in decision-making (Howarth et al., 1984).

In a more recent study, Hopwood et al. (2011) used a high-speed video analysis approach to study the anticipation ability of fielding in cricket. The participant stood in a cover position and fielded balls hit from the batsmen. High-speed cameras placed behind the fieldsman measured the amount of time the fielder took to make a movement in the correct direction following ball contact. Fieldsmen, following a perceptual-training intervention, were able to decrease their movement initiation time showing an improvement in anticipatory ability.

Another valuable field-based approach is the use of visual occlusion techniques. Visual occlusion differs to film-based occlusion in that the participant is in a specific performance setting, responding to a real-life stimulus, rather than viewing a film display. The researchers then use some device that occludes the participant’s vision of the stimulus. This can include a mask, goggles, etc. An early study into anticipation using the visual occlusion technique was undertaken by Day (1980). The tennis specific study saw the participants standing on the baseline on the court attempting to return balls from an opponent who was instructed to hit forehand shots to any part of the court. Participants wore visual occlusion helmets that occluded their vision upon racquet-ball contact of the opponent. This was done via a pressure sensor on the opponent racquet which, when ball-contact was made, activated an electronic shutter upon the helmet, thus occluding vision.
The results echoed earlier studies in that high-skilled players displayed greater anticipation ability through the use of advance cue utilisation than the low-skill players.

In more recent studies, researchers have made use of the liquid crystal occlusion technique for studying advance cue utilisation. These liquid-crystal occlusion spectacles were developed in order to study the decision-making and visual information processing behaviour of automobile drivers (Milgram, 1987). These glasses have liquid-crystal cells comprising nematic and cholesteric materials, which align with each other when an electrical signal is applied. When these materials are aligned, the lenses of the glasses are transparent and thus the person can view the situation. When the electrical signal is removed, the lenses take on a ‘milky’ texture that blocks the person’s vision. Therefore, with an attached cable that provides the electrical signal, the researcher can control when the spectacles occlude the vision of the participant, therefore preventing them from acquiring visual information from the environment (Milgram, 1987).

In one of the first studies to employ the new technology, Starkes, Edwards, Dissanayake & Dunn (1995) examined the differences between experts and novice volleyball players in terms of their ability to use advance visual cues for anticipation. Participants stood in the middle of a volleyball court whilst wearing the liquid-crystal spectacles. The participants’ aim was to view an opposition player serving the ball and make a prediction on where the ball landed on their side of the court. Participants had to rely on advance visual cues as their vision was occluded at pre-contact, contact or post-contact intervals. Additionally, participants stood on a foam mat in order to eliminate any information that may have been gathered from feeling vibrations when the ball made contact with the ground, and listened to music played through headphones to eliminate auditory information. Following the
serve, participants placed a marker on the court where they believed the ball had landed. The distance of the prediction marker from the actual landing position was the dependent measure. Results found that the skilled players had a greater ability to predict ball landing position than their novice counterparts, indicating their greater ability to effectively utilise advance cues in anticipation (Starkes, Edwards, Dissanayake, & Dunn, 1995).

More recently, liquid-crystal occlusion spectacles were used to assess the differences in ability of highly skilled and low skilled cricket batsmen to utilise advance visual cues in order to strike cricket balls delivered from fast bowlers (Müller et al., 2009). Batsmen wore the liquid-crystal occlusion glasses whilst facing deliveries from three different fast bowlers. Vision was occluded at either the point of ball release or at a point just prior to ball bounce. In addition, a control condition was included where no occlusion took place. The results showed that the highly skilled batsmen had a greater ability to utilise advance cues to make ball-to-bat contact than the low skilled group. The results of this study emulated a previous cricket study that also utilised liquid-crystal occlusion glasses. Muller and Abernethy (2006) found that high skilled batsmen exhibited a superior ability to make use of advance visual information (pre-bounce) in order to guide bat-ball interception in comparison to low skilled batsmen (Müller & Abernethy, 2006).

The ability of high skilled athletes to interpret and utilise advance visual information in order to accurately anticipate future events within the performance setting has been proven on numerous occasions in the literature. This has been done via both laboratory-based tests (film based temporal/event occlusion, reactions time paradigms) and field-based tests (high speed video analysis, visual occlusion techniques).
2.2.2.3 Pattern Recognition

A further component of anticipation is the ability to identify familiarity within sequences of play (Williams, 2009). This component has largely been studied in the realm of cognitive psychology; however its application to anticipation for sports performance has become increasingly apparent.

Research has focused on the ability of athletes to encode and retrieve task-specific information. As stated by Williams (1999) “Encoding refers to how information is transferred into a form that can be stored in memory, whereas retrieval refers to the way information within the memory is accessed in order to respond to the task at hand” (p.97). The ability to encode and retrieve information for anticipation in sport has been studied predominantly through two methods; the ‘recall’ and the ‘recognition’ paradigms.

The recall paradigm features participants viewing film displays of structured and unstructured periods of play from the performance setting. Structured periods of play include typical sequences as seen in the performance setting whereas unstructured sequences include players warming up, during a time-out period, etc. The ability of the participant to recall the positions of players from the film following the viewing of the display gives an indication of their recall ability.

The recall paradigm was originally studied in the context of skilled chess players (de Groot, 1965). This study compared the recall ability of chess masters in comparison to club players. Players viewed a game configuration for a period of 5-10 seconds. Following the viewing of the display, players had to recall the position of chess pieces from memory. Results indicated that the master players had a recall ability of 91% in contrast to 51% for the club players. This study was extended upon by Chase and Simon (1973) who also
compared differences between grand master, A-level and club chess players. Configurations of chess pieces were shown in two formats; structured and unstructured. Structured configurations were of typical chess configurations whereas unstructured configurations featured totally random positions. The results mirrored those found by de Groot (1965) in that experts were more able to recall chess piece position from memory (Chase & Simon, 1973). This skill however was only apparent during the structured configurations as no difference was found in the unstructured displays. The authors attributed this to the notion that expert players have a larger and more advanced task-specific knowledge base in addition to greater skill in retrieving this information (Chase & Simon, 1973). In a basketball specific study, Allard and Burnett (1985) compared players to non-players recall ability after a 4 second view of a static slide featuring structured (attacking play patterns) or unstructured (time-out) situations. Participants, after viewing the display placed markers where they believed the players were located in the display. Results echoed those found amongst chess players in that basketball players had a greater ability to recall positions of players in the structured scenes, however no distinction could be drawn between groups after viewing the unstructured slides (Allard & Burnett, 1985).

The recall ability of expert athletes in structured tasks has been replicated across a multitude of sports. It has been proposed that this ability is based on experts having an enhanced sport-specific knowledge base, which in turn allows these athletes to more effectively encode and retrieve information (Williams et al., 1999). As stated by Williams et al. (1999) “this knowledge base enables them to recode the visual display into fewer, larger ‘chunks’ of information that can be more easily remembered and then decoded to reproduce the original pattern” (p.99).
The study of an athlete’s ability to encode and retrieve task-specific information is also tested via the recognition paradigm. The recognition paradigm involves participants being shown video clips of structured and unstructured sequences of play. Participants are then shown a similar sample of video clips, some of which were shown in the original sample. The athletes are then scored on their ability to recognise which video clips were shown in the original sample.

The recognition paradigm was first used in a basketball-specific study (Allard, Graham, & Paarsalu, 1980). The researchers presented 80 slides featuring structured and unstructured sequences of play to skilled and novice participants. The athletes then had to recognise which slides had already been viewed in the earlier completed recall task. The researchers found that the skilled participants were significantly more accurate in recognising previously viewed sequences of play. This skill however was only demonstrated in response to the structured sequences of play (Allard et al., 1980). The researchers made the suggestion that the higher skilled basketballs encode the task-specific information to a deeper level, which aides them in recognising the pattern of play when it is re-shown. The same result was found in a similar study completed in the context of snooker (Abernethy, Neal, & Koning, 1994). Experts were found to have a greater ability to recognise slides that had been previously viewed, however this was only seen in response to structured slides whereas no difference between skill levels was apparent in recognition ability of unstructured slides with randomly placed snooker balls.

It has been suggested that a crucial issue in recall and recognition studies is the extent to which these abilities relate to skilled performance. It is questioned whether an expert’s superior performance on recall and recognition tests is a result of greater task experience
and familiarity, as opposed to greater task-specific expertise (Williams et al., 1999). Williams and Davids (1995) attempted to answer this question when they used large video projection screens that showed 10-second action sequences of professional soccer matches. The use of video and a large screen negated potential limitations of previous studies that employed static film slides shown on small monitors. These sequences were either structured (offensive plays ending in a shot at goal or pass) or unstructured (e.g. player’s warming-up or receiving injury treatment). These videos were filmed from behind the goal, providing the participants with a perspective similar to that used in the game. Other studies have shown participants action sequences from an elevated position or other representations not associated with an athlete’s perspective. Using video from the athlete’s point-of-view may provide researchers with more accurate results as opposed to other viewing perspectives. The objective of the study was to determine whether superior recall performance was a result of experience or a characteristic of expertise (Williams & Davids, 1995). The participants within the study had the same level of experience (number of matches played, amount of training, degree of coaching, number of matches watched), however they had different levels of skill (amateur players and semi-professional players). A control group of physically disabled spectators were used who had no physical experience of the game. The results showed that the semi-professional group of players outperformed the amateur players on the recall test (Williams & Davids, 1995). This result suggests that recall ability is a component of expertise rather than a by-product of sport experience (Williams & Grant, 1999). In addition, the results showed that both the semi-professional and amateur players outperformed the control group of disabled spectators in the recall test. It is therefore apparent that playing soccer promotes the acquisition and retention of soccer-specific declarative knowledge (Williams & Davids, 1995).
Williams and Davids (1995) also included a recognition component of testing. Participants had to recognise which of the action sequences had been previously viewed within the recall test. The researchers also tested the participants for how long it took to recognise previously seen action sequences. The basis for this inclusion was that recognition performance within the applied setting is completed under temporal constraint; therefore it could be hypothesised that experts can recognise previously seen sequences faster than less-skilled counterparts. The results supported this hypothesis in that the higher-skilled players recognised previously viewed sequences of player faster and more accurately than the less skilled participants (Williams & Davids, 1995).

Studies utilising recall and recognition paradigms have been effective in demonstrating that the ability to recall structured patterns of play in addition to recognising previously viewed structured action sequences are indeed components of expertise. A regression analysis was completed as part of Williams and Davids (1995) study to show that performance on a recall and recognition test could be predicted based upon an athlete’s performance upon a film-based anticipation test, thus indicating that the ability to recall/recognise structured patterns of play is an important component of anticipation (Williams & Davids, 1995).

2.2.2.4 Situational Probabilities

In addition to an expert performer’s ability to use advance cues and recalling/recognising patterns of play, it is also apparent that experts are able to use subjective situational probabilities in order to aid anticipation. Experts can draw on their more advanced knowledge base to eliminate events as being ‘highly improbable’ and can attach a hierarchy of probabilities to the remaining events (Gottsdanker & Kent, 1978). By doing
so, athletes are able to reduce both event uncertainty (what will occur) and temporal uncertainty (when it will occur) (Williams et al., 1999).

Alain and Proteau (1978) studied the athlete’s use of situational probabilities in anticipation within racquet sports. Rallies from squash, racquetball, tennis and badminton, were filmed with the participants asked questions regarding shot selection during the rally. The athletes had to classify each stroke into probability levels in terms of how confident they were in their opponent’s shots. The results showed that as confidence levels exceeded 70%, players displayed a greater frequency of anticipatory movements (as determined by movement in the required direction). This showed that as player’s confidence in their subjective probabilities rose, this was used as a major anticipatory cue (Alain & Proteau, 1978).

Paull & Glencross (1997) assessed both novice and expert baseball players in their ability to set probabilities of pitching location based on the situation. The results found that both groups of players were effective in their ability to set probabilities based on the current game situation. This in turn led to more effective anticipation time as shown by a faster response time (Paull & Glencross, 1997).

Ward and Williams (2003) assessed the role of situational probabilities in anticipation within the context of soccer. The study focused on the differences between junior elite and junior sub-elite players at different age groups (U9, U11, U13, U15, and U17). Participants were shown 10 second video clips, which showed an 11 v 11 offensive situations filmed from an elevated position behind the goal. The video clip was frozen 120ms prior to the player in possession passing the ball. The still image of the 11 v 11 situation remained on the screen for 20 seconds while the participants were asked a series of questions. The
participants were asked to highlight key players in a good position to receive the ball, based on players expectations of what should happen next. The participant then ranked each highlighted player in terms of his perceived attacking importance (Ward & Williams, 2003). The participant’s responses were matched against a panel of expert coaches. The elite group of players were shown to have a greater understanding of the situation than their sub-elite counterparts. The elite players highlighted a greater number of key players within the video clip. In addition, elite players were able to predict the next best move for the attacking player with the ball by indicating a probability hierarchy to the most important players. Elite players were also more accurate in excluding non-key players who did not pose an immediate threat to the attack (Ward & Williams, 2003). Ward and Williams (2003) therefore put forth the notion that “by using a more refined selection strategy and probability hierarchy, developing elite players are able to decrease the decision threshold necessary to predict the likely outcome of a situation” (p. 106).

Abernethy et al. (2001) found that experts had a greater ability to anticipate shot direction from an opponent after visual occlusion occurred. As discussed previously, experts had a greater ability to extract information garnered from the opponent’s hitting action. In addition, experts were found to have a greater ability to anticipate shot direction even when vision was occluded prior to the onset of the opponent’s hitting action (Abernethy et al., 2001). This indicated that the players were able to use situation probabilities as a major source of anticipatory information. Farrow and Reid (2012) also demonstrated the importance of situational probabilities on service location anticipation in tennis. The researchers used a projector that displayed an opponent serving from a returner’s viewing perspective. The participants (nationally ranked 11 and 18 year olds) were shown the game score prior to viewing the action clip. Participants predicted service location by touching
the touch-screen monitor. It was found that the older players had the ability to accurately indicate the service location prior to the commencement of kinematic cues from the server becoming apparent. Therefore, it was assumed that these players were able to anticipate direction based on the situational probabilities presented by the game score (Farrow & Reid, 2012).

2.2.2.5 Visual Search Behaviour

A fundamental element of perceptual-cognitive skill is the use of ‘visual search’. The visual search process is integral to sports performance as it allows for the acquirement of information from the environment that is essential in determining what to do in a given instance (Magill, 1993). Williams, Janelle and Davids (2004) defined visual search strategy as “the way in which the eyes are used to search the display or scene for relevant information to guide action” (p. 301). Additional definitions have been proposed by Zelinsky et al. (1997) as “the process by which one locates a target in a cluttered scene” (p. 448), and also by Sternberg (2003) as “the scan of an environment for particular features - actively looking for something when you are not sure where it will appear” (p.83).

Effective visual search is very important in the performance of agility type movements in sport-specific settings as the early detection of stimuli is a trigger for fast and accurate movements. A significant amount of literature now suggests that experts search the display in a more systematic and efficient manner than novices (Williams, Janelle, & Davids, 2004). The majority of research into visual search has focused on visual fixations. These fixations separate saccadic eye movements, which shift the informative area of the display from the periphery to the focus point, known as the fovea (Williams et al., 1999). As stated
by Williams et al. (1999) “visual fixations allow the performer to stabilise an informative area of display, enabling more detailed processing to occur” (p.146).

As mentioned previously in the discussion on advance cue utilisation, experts have developed a task-specific knowledge base that they can draw upon during performance to aid anticipation. This knowledge base allows the performer to direct their visual search strategy towards the most information-rich areas of the display and therefore pick-up the most anticipatory information (Williams et al., 1999). This was evident in Tyldesley, Bootsma and Bomhoff (1982) study into visual search strategy in soccer. Participants were shown static slides of opposition players executing penalty kicks. The researchers then compared the visual fixation location of experienced and inexperienced goalkeepers in addition to performance success, as indicated by the participant selecting from response keys representing anticipated shot direction. The researchers found that 60% of initial fixations of the experienced goalkeepers were aimed at the hips of the penalty taker (Tyldesley, Bootsma, & Bomhoff, 1982). Williams and Burwitz (1993) found similar results in that experienced goalkeepers focused predominantly in the hip region in anticipating penalty direction. In addition, whilst studying the visual search strategy of gymnasts at different skill levels, Vickers (1988) found that the more elite gymnasts directed their gaze towards the torso area of the gymnasts, showing they had a greater understanding of the role of the centre of gravity in the performance of complex movements than their less-elite counterparts (Vickers, 1988).

These results were extended to anticipation of which direction an opposition player was to dribble the ball in soccer (Williams & Davids, 1998). Williams and Davids (1998) hypothesised that “perhaps the experienced players focused on the hip region because of
its proximity to the center of gravity. When the dribbler moves left or right, there must be a displacement in the center of gravity in the corresponding direction” (p.119). This insight by the researchers may be directly related to anticipating stepping direction in rugby league. Using the above notion, a defensive player monitoring the attacker’s hips may be able to anticipate movement direction by the information garnered from any change in the player’s centre of gravity.

An additional feature of the existing research into visual search strategy is the assessment of the number of fixations the athlete makes and also the duration of each fixation. Mann, Williams, Ward and Janelle (2007) concluded through their research that experts in sport are characterised by fewer fixations of longer duration. They supported the notion that expert performers are able to gather more information from each fixation than less skilled performers (Mann, Williams, Ward, & Janelle, 2007). However, this is in contrast to other studies, which suggest that expert performers make a greater number of fixations of a shorter duration (Causer, Holmes, & Williams, 2011). Afonso, Garganta, McRobert, Williams, & Mesquita (2012) studied visual search qualities of high-skilled and skilled volleyball players using eye-tracking technology. It was found that the high-skilled players made a larger number of fixations of shorter duration to several locations in comparison to the skilled playing group (Afonso et al., 2012). These results reflect the results of additional studies amongst other sports including cricket (McRobert, Williams, Ward, & Eccles, 2009) and soccer (Roca, Ford, McRobert, & Williams, 2011).

Initially, research focused on electing the most efficient visual search strategy; however in contrast to a ‘one size fits all’ approach, where experts across multiple domains are suggested to use the same visual search strategy, it is now proposed that a number of
constraints impact upon how the performer uses visual search strategies to pick up information from the environment (Williams, Janelle, & Davids, 2004). A summary model of these constraints is shown in Figure 2.2.

As shown in Figure 2.2, constraints related to the nature of the task, environment and organism all have an impact upon the visual search behaviour employed by the athlete (Williams, Janelle, & Davids, 2004).

Figure 2.2: Constraints on Visual Search Behaviour during sports performance (Williams, Janelle, & Davids, 2004)

Task constraints, including task goals and tactics employed, have an effect on visual search strategy employed by the athlete. Williams and Davids (1998) studied the differences in visual search behaviour in response to 1-v-1 and 3-v-3 soccer situations. The researchers found that skilled players had shorter mean fixation duration during the 1-v-1 situations.
and a greater number of fixations during the 3-v-3 situations (Williams & Davids, 1998). These results were also compared to an earlier study into the visual search behaviour in 11-v-11 situations (Williams, Davids, Burwitz, & Williams, 1994). The researchers (Williams, Janelle, & Davids, 2004), hypothesised that within the 11-v-11 situations, where the ball was usually some distance away, the athletes relied on scanning the environment in a more comprehensive manner by making more fixations. During the 3-v-3 and 1-v-1 situations, the role of the information gathered from the periphery increases and thus the number of fixations decreases (p.308).

The nature of the task, being either open (externally-paced) or closed (self-paced) is an additional task constraint that can affect visual search behaviour. It has been suggested that within self-paced tasks, rather than scanning the environment for information, athlete’s focus their visual attention on only a few key areas prior to initiating action in order to eliminate distractions from irrelevant task information (Williams, Janelle, & Davids, 2004). This occurrence has been termed the ‘quiet eye period’ (Vickers, 1996). The difficulty of the task will determine the length of the quiet eye period with more challenging tasks requiring a longer duration of fixation (Williams, Singer, & Frehlich, 2002). It is during this time that the performer prepares the motor response (Gallucci, 2008).

Organismic constraints including fitness level, technical proficiency, visual abilities such as depth perception and acuity may have an effect on visual search strategy (Williams, Janelle, & Davids, 2004). The effect of emotion on search behaviour has been seen via the change in search behaviour under different levels of anxiety. Williams and Elliott (1999) found that skilled and less skilled karate performers significantly altered their visual search
behaviour under varying levels of anxiety. When highly anxious, the performers extracted less information from the periphery and also showed an increase in the number of fixations (Williams & Elliott, 1999). The effect of anxiety to limit the amount of information gathered from the periphery has also been shown in table tennis (Williams, Vickers, & Rodrigues, 2002).

The impact of environmental constraints upon visual search behaviour has been shown by studies comparing video film and the same stimuli under ‘point-light’ conditions (Horn, Williams, & Scott, 2002; Ward, Williams, & Bennett, 2002). These studies found that under the point-light condition, athletes employed fewer fixations of longer duration to a smaller number of fixation locations. It was therefore hypothesised that the athletes efficiency to pick up relevant information was negatively affected by the environmental information within the video display (Williams, Janelle, & Davids, 2004).

Generalised visual training programs have been advocated in some parts of the literature. These programs generally include pre-existing clinical optometry exercises with the aim of improving basic visual functions such as acuity, eye tracking and depth perception (Abernethy & Wood, 2001). These programs have been claimed to improve visual function and in turn sporting performance (Revien, 1981). The value of these generalised visual training programs rely on the assumptions that: i) vision is directly related to sports performance; ii) the key visual attributes for sports performance can be trained; and iii) improved vision translates to improved sports performance (Abernethy & Wood, 2001). The first assumption is disputed as it has been demonstrated that elite athletes have a high incidence of uncorrected visual defects (Garner, 1977). Starkes and Deakin (1984) also determined that elite and non-elite athletes were not characterised by differences in visual
function. The differences between skill levels are considered to be a result of perception and visual interpretation rather than visual function (Abernethy & Wood, 2001). Perceptual-cognitive abilities including sport-specific pattern recognition and anticipation have been shown to distinguish skill groups when basic visual function was similar between groups (Starkes, 1987). In the clinical setting, visual function training programs have been proven effective in a range of improvements. However, much of this research has focused on improving visual function in individuals with visual defects rather than athletes. The possible existence of a ceiling for general visual improvement may suggest that athletes with normal and above average visual function may not benefit from the proposed visual training programs (Abernethy & Wood, 2001). The final assumption of generalised visual training programs is that any improvement in visual function will automatically transfer to improved sports performance. The literature relating visual function to sports performance is limited and thus claims supporting this causal link are anecdotal and not supported via empirical studies (Williams & Grant, 1999).

2.2.2.6 Interaction of Perceptual-Cognitive Skills

Four components of perceptual-cognitive skill have been outlined, those being (a) the ability to extract and utilise information from an opponent’s body orientation, (b) the ability to recognise patterns of play, (c) the ability to predict action based on situational probabilities and (d) the ability to accurately and efficiently search for information within the environment. As opposed to being used independently, it is suggested that these skills interact with each other in a dynamic and evolving manner (Williams & Ward, 2007). Williams (2009) has proposed “that the relative importance of these perceptual-cognitive skills may vary based on a range of constraints related to the task, situation, and
performer” (p.79). These constraints are shown in Williams (2009) model, presented earlier (see Figure 2.2).

First, task constraints, as defined by Williams, Janelle, & Davids (2004), “include the goal of any task, any implements such as sticks or rackets that must be employed to satisfy the goal, and the rules, strategy, and tactics inherent to a sport” (p. 306). Task constraints can affect how important the use of each perceptual-cognitive skill is within a specific task. For example, within team ball sports (e.g. rugby league, soccer, hockey) the ability to identify stimulus familiarity in patterns of play is important for anticipation, whereas the ability to anticipate based on opponent bodily orientation maybe more important within racquet ball sports, such as tennis and squash (Williams, 2009).

Secondly, situational constraints may also greatly affect the relative importance of each perceptual-cognitive skill. Situational constraints include variables such as where the player is located on the field (half way, near goal, etc.), distance between the individual and opposing players, whether they in possession of the ball or not, etc. (Williams, 2009). These factors have an effect on the level of temporal constraint on the individual’s decision-making and also influence the positive/negative effects of a correct/incorrect anticipation judgment. For example, if a player is defending on the edge of their 18 yard box in soccer against a player in possession of the ball, their time to make a decision is limited and the consequence of making an incorrect judgment could be great i.e. a goal scored against the team. In contrast, a player defending on the halfway line with the opposition in possession, while facing their own goal, has more time to factor in relative information and the consequence of an incorrect decision is less costly for the team. These differences have an effect on the perceptual-cognitive skills employed by the individual.
The player defending on the edge of his own box may only anticipate action based on postural orientation of the attacker and situational probabilities on what the attacker is likely to do. In contrast, the player defending on halfway may be able to draw more information from pattern recognition as they have a greater time allowance to assess the overall situation.

Thirdly, player constraints, also referred to as ‘organismic constraints’, are defined by Williams, Janelle, & Davids (2004) as:

the unique structural characteristics of performers and include, for example, factors related to their physical, physiological, cognitive, and emotional make up. A performer’s morphology, fitness level, and technical proficiency as well as psychological factors such as anxiety or achievement motivation may act as pressures to channel the manner in which a performance goal is approached. (p.305)

These factors have a great effect on the use of each perceptual-cognitive skill. Players who are highly anxious may narrow their attention capacity and therefore be unable to utilise information from the periphery, meaning they are making anticipation judgments based almost solely on information arising from the opponent with the ball. In addition, players who are fatiguing may have difficulty in directing their attention to external sources of information as they are more focused on their own condition. Perceptual-cognitive strategies involving directing attention to the opposition players may become somewhat redundant in this situation and the use of situational probabilities may become greater (Williams, 2009). In summary, in anticipatory judgements, these perceptual-cognitive skills work with each other in a dynamic fashion, with the importance of each being greatly affected by constraints related to the task, situation and player.
2.3 Biomechanics and Anticipation

It has become apparent that experts are able to extract more relevant postural cues from their opponents earlier in the action sequence in order to aid in anticipation (Farrow, Young, et al., 2005; Jackson et al., 2006; Jones & Miles, 1978; Salmela & Fiorito, 1979; Williams & Burwitz, 1993). This has been shown even when the opposition player has attempted to disguise their intentions or deceive the reactor (Jackson et al., 2006). As a result of this knowledge, studies have progressed to determining the most accurate predictors of future running direction by employing biomechanical analyses.

Brault, Bideau, Craig & Kulpa (2010) employed a biomechanical analysis within their study into 1-v-1 situations in rugby union. The researchers examined how attacking players attempt to deceive the defender as well as disguise their true intentions. Amateur players performed a 1-v-1 duel where the attacker attempted to eliminate (evade) the defender. High speed cameras were used to capture the movements of the attacker. A biomechanical analysis was undertaken to compare the locomotion differences between effective deceptive movements, ineffective deceptive movements, and non-deceptive movements. The results showed that during deceptive movements the expert attacking players exhibited a strategy involving two processes: (i) the use of false parameters to mislead the defender into thinking the attacker will run in the opposite direction, and (ii) the minimisation of other parameters in order to keep postural stability flexible so that the attacker can still change their final running direction (p. 423). The study showed that attackers minimised both their centre of mass (COM) displacement and lower trunk yaw during deceptive movements. In addition, out-foot displacement, head yaw and upper trunk yaw were exaggerated during deceptive movements (Brault et al., 2010).
researchers commented that the most significant angular changes were found in the upper trunk, as attackers exaggerate the shoulders movements in the opposite direction to where they will run. Additionally, it was hypothesised that by exaggerating upper body movements, the defender’s attention would be taken away from the pelvic region that offers more abundant information in terms of anticipating future running direction (Brault et al., 2010).

In a follow up study, it was found that when anticipating the direction of an attacking player’s step, novice players were more attuned to deceptive signals (upper trunk yaw) in contrast to the expert performers who were more focused on the ‘honest’ (centre of mass) signals. It was concluded that the expert performers were extracting relevant information from the honest signals. As a result they made fewer errors than the novice group and were able to utilise these signals to successfully guide their actions to intercept the attacking player (Brault, Bideau, Kulpa, & Craig, 2012).

2.4 Response Time

Recent definitions of agility have begun to address the reactive nature of agility performance. These definitions highlight the importance of being able to react to a stimulus in a fast and efficient manner and move accordingly. An athlete who displays a high level of agility would demonstrate enhanced reaction time, movement time and therefore response time.
Reaction time (RT) is defined by Magill (2007) as “the interval of time between the onset of a signal (stimulus) and the initiation of a response” (p. 25). Movement time (MT) is defined by Magill (2007) as “the interval of time between the initiation of a movement and the completion of the movement” (p. 25). Response time is the total time, thus incorporating both reaction time and movement time. The relationship between the three measures is shown in Figure 2.3.

It is important to note that both reaction time and movement time are independent measures i.e., RT performance is not predictive of MT and vice versa. This means from a practical application, high performers in terms of RT may not display high levels of MT. Alternatively, athletes who demonstrate effective MT may have poor reactive abilities as determined by RT (Henry, 1961). This would have important implications for the types of training protocols used.

Reactive tasks can be of three types. These are: i) simple, ii) choice and iii) discrimination. Simple RT is displayed when the situation involves only one signal (stimulus) that requires only one response. An example of simple RT is the starter’s gun in a 100 m sprint. The
athlete only has to react to the one stimulus, the sound of the gun, and the only response is to start the race. Choice RT is demonstrated when the situation involves more than one signal (stimulus) and each signal requires its own specified response. An example of choice RT is traffic lights encountered at an intersection. Each different stimulus, green/amber/red light, is paired with its own response; go/prepare to stop/stop. Discrimination RT is displayed when a situation involves various stimuli and there is only one response, however only one of the stimuli requires the response, the other signals require no action (Magill, 2007, p. 27). An example of discrimination RT is a 10 m sprint test using flashing light gates. The athlete’s only response is to initiate the sprint, however, the athlete may only do so after the green light appears, whereas they must ignore, red and blue flashes (multiple stimuli).

Reaction time is influenced by a number of factors. One of the major factors is the numbers of response choices. In simple RT tasks, the performer is only required to react to one stimulus with the one response. However, “as the number of alternatives increases, the amount of time required to prepare the appropriate movement increases” (Magill, 2007, p. 170). This principle is shown in choice RT situations where the reaction time increases as the performer must interpret the stimuli and initiate the appropriate response. This principle was developed into what is now referred to as Hick’s Law (Hick, 1952). This law demonstrates that when a person’s simple RT is known, their reaction time will increase logarithmically as the number of response choices increase. This is shown in Figure 2.4.
This has important implications for reactive situations in a sporting environment. Novice athletes who have a smaller task specific knowledge base may view a situation as having a multitude of choices (response options) as opposed to elite athletes who over time have developed a large task-specific knowledge base. This knowledge base and use of situational probabilities allows an athlete to produce a ‘probability hierarchy’ (Gottsdanker & Kent, 1978) of responses and reduces the number of choices (responses), which may increase their reaction time.

### 2.5 Video Training

The benefits of implementing video technology into training methodologies are currently being researched in a number of disciplines. The value of video technology to training has been studied in surgical trainees (Jowett, LeBlanc, Xeroulis, MacRae, & Dubrowski, 2007). These surgical trainees were shown to improve their technical surgery skills after utilising self-paced video training. The researchers also highlighted the additional advantages of video training in comparison to laboratory-based learning, including cost and time benefits. Cadet pilots have also been subject to video training studies (Gopher,
Well, & Bareket, 1994). This study, using 18-20 year old flight cadets, utilised flight simulators for ten one-hour sessions and compared the learning effects with a control group. It was found that the video simulation training group significantly outperformed the control group in a flight performance test following training. Elderly vehicle drivers have also benefited from video training research (Roenker, Cissell, Ball, Wadley, & Edwards, 2003). These adults were shown to improve their safe driving skills after driver simulation training was completed.

The major advantage of video training is its ability to simulate situations encountered during performance. Performing these situations in “real world” environments can be time consuming, costly and may be of high risk. However, video training used for pilot training are able to simulate the experience of flying a plane in a repeatable, lower cost, lower risk setting.

The advantages of video training are now being studied in relation to sports training (Hopwood et al., 2011; Serpell et al., 2011). The ability of video training to replicate on-field situations has been and is being continually studied for its ability to improve athletic performance. As in the non-sporting context, video training for athletic performance offers the benefit of training in repeatable situations that replicate the performance setting. Video training eliminates the constraints posed by replicating the performance setting including, the required expertise of coaches, and the probable large number of athletes required. The main purposes for implementing video training in the past have been for skill learning, performance feedback, and to study opposition tactics. With the recognition of the importance of the perceptual-cognitive components of skilled agility performance, video training offers a valuable tool for sport-specific agility testing and training protocols. The
use of video training within agility testing and training protocols are discussed in the following sections.

2.6 Agility Testing

As the definition of agility has been constantly evolving throughout the literature, so too has the mechanisms and methodologies by which it has been tested. As previously mentioned, strength and conditioning coaches have primarily employed pre-planned sprints with changes of direction in order to test for agility (Baker & Newton, 2008; Draper & Lancaster, 1985; Meir et al., 2001; Pauole et al., 2000; Semenick, 1990). Recently however, research has begun to focus on testing the reactive component of agility (Farrow, Young, et al., 2005; Gabbett, Kelly, & Sheppard, 2008; Meir, Holding, Hetherington, & Rolfe, 2012; Serpell et al., 2010).

Chelladurai (1976) was one of the original researchers that noted that agility was a measure of both an athlete’s movement and reactive abilities. As previously mentioned, Chelladurai (1976) noted that different tasks involve different levels and types of uncertainty. Chelladurai therefore proposed that athletic tasks could be classified into four categories; i) ‘simple’, i.e. there was no spatial or temporal uncertainty associated with the task (e.g. gymnastics floor routine); ii) temporal uncertainty, i.e. the athlete was unaware when the stimulus would present itself however spatial certainty remained (e.g. a starter’s gun in the 100m race); iii) spatial uncertainty, i.e. the athlete was unaware where the stimulus would present itself however temporal certainty remained (e.g. receiving a tennis serve); and iv) universal uncertainty, i.e. the task involves both spatial and temporal uncertainty (e.g. open type sport situations).
Chelladurai et al. (1977) developed a novel testing battery to assess the effect of the differing uncertainty levels on movement times. The testing set-up included a ‘reaction mat’ which participants stood upon at the beginning of the test. This reaction mat included a pressure sensor, which completed an electrical circuit of the timing clock, thus when the participant left the mat, the circuit was broken and the clock stopped, thereby recording reaction time. Directly in front of the reaction mat (2.44m away in distance) was the light display, which included twelve light bulbs each with its own touch plate. The athlete started the test with both feet on the reaction mat and when ready pressed the activator switch, which caused one of the light bulbs to light up. In response to the light bulb, the participant moves forward and touches the touch plate on the highlighted light bulb and then returns to repress the activator switch which completed the trial.

The study used sixty male university students who each performed forty trials spread evenly across four conditions. These four conditions varied in terms of their stimulus variation and included ‘simple’, where the centre bulb lit up as soon as the participant pressed the activator switch, therefore there was no spatial or temporal uncertainty; ‘temporal’, where the centre bulb lit up at any time between 0 and 3 seconds after pressing the switch, therefore temporal uncertainty was introduced whilst there was no spatial uncertainty; ‘spatial’, where any of the twelve bulbs lit up immediately after the switch was pressed, therefore spatial uncertainty was present whilst temporal certainty was maintained; and ‘universal’, where any of the twelve bulbs could light up at any time between 0 and 3 seconds, therefore both temporal and spatial uncertainty was present.

The results indicated that the variations in the stimulus presentation, i.e. simple, temporal, spatial or universal, had a significant effect on both total time and forward time of the
participant. As shown in Table 2.3, both total time and forward time in response to simple stimuli resulted in the fastest times whereas uncertainty in the form of either spatial or temporal variations resulted in slower times by comparison. When the stimulus presented involved universal uncertainty, the athlete had to process more information and thus took longer time to respond and move. Therefore, this was one of the first studies that showed that the perceptual-cognitive component of agility significantly affects the total movement time.

Table 2.3: Total Time and Forward Time (seconds) in Four Agility Tasks (Chelladurai et al., 1977)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Statistic</th>
<th>Simple</th>
<th>Temporal</th>
<th>Spatial</th>
<th>Universal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Time</td>
<td>Mean</td>
<td>1.51</td>
<td>1.93</td>
<td>1.92</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.17</td>
<td>0.17</td>
<td>0.12</td>
<td>0.16</td>
</tr>
<tr>
<td>Forward Time</td>
<td>Mean</td>
<td>0.81</td>
<td>1.22</td>
<td>1.17</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.14</td>
<td>0.12</td>
<td>0.09</td>
<td>0.13</td>
</tr>
</tbody>
</table>

One of the first studies focusing on testing agility was conducted by Farrow et al. (2005). In this netball specific study, participants from lesser, moderately and higher skilled playing groups were assessed using life-size video projections. These video projections showed an opposition player executing a netball-specific pass. The participants were required to respond to the video by moving in the direction in which the pass was directed, thus mirroring a defensive response. A high-speed camera capturing at 50 Hz (frames per
second) was positioned behind the participant and measured the time between the occlusion of the sport-specific stimulus and the player’s movement initiation. This quantified the participant’s decision-making time. Light gates were used to measure the total test time. It was found that higher-skilled players’ response time (time from stimulus onset to participant’s reaction) was significantly faster in comparison to the lesser-skilled players (Farrow, Young, et al., 2005). The difference between total movement times was attributed to the increased speed of response, as pre-planned movements were unable to discriminate between the playing levels among netballers.

More recently, a similar protocol was used specific to rugby league (Serpell et al., 2010). In this study, a high performance group was compared to a low performance group in relation to their performance in a reactive agility test (RAT). Video projections were produced using high-level players. These videos, filmed from a defender’s point-of-view, showed the attacking player running towards the camera and then executing a 45 degrees change-of-direction, which could also include a fake and also a pass. The participant, after running forward approximately 8 metres, then had to respond to the video projection and move in the correct direction. Light gates were used to record total test time and a high speed camera was used to quantify response time. The same methodology was used without the use of video projections in order to test for change-of-direction speed (CODS). The results mirrored the results found by Farrow et al. (2005) in that significant differences were found between the higher and lower performance groups only when the reactive task was included. Thus, playing groups could be discriminated by their agility where no discriminations could be made on the CODS test.
Reactive agility testing protocols have also been developed specific to Australian Rules football (Henry et al., 2011; Young, Farrow, Pyne, McGregor, & Handke, 2011; Young & Willey, 2010). Henry et al. (2011) studied the agility performance differences between high-level players, low-level players and non-footballers; testing was completed using a number of methodologies. First, agility was tested using both a light-based and a video-based RAT. The light-based RAT utilised ‘Smart Speed’ light gates, which required the participant to run towards the timing gate as indicated by a coloured light. Within the video-based RAT, participants responded to sport-specific video projection and moved in accordance with the video stimulus. These tests were compared with a planned agility test, i.e. CODS. The results indicated that the higher-level groups significantly outperformed the low-level players in the video-based RAT but no difference was found in the CODS test.

Further efforts have been made to couple reactive agility testing while simultaneously quantifying performance success (Hopwood et al., 2011). Whilst testing reactive speed in cricket fielding, Hopwood et al. (2011) also tested for fielding success. The participant was standing in a fielding position, waiting for a batsman to strike the ball between two cones on either side of the participant. High-speed cameras, capturing at 25 Hz, were placed behind the fieldsman quantified the participant’s response time. In addition, fielding success was also recorded based on whether the fieldsman was successful in stopping the ball. This pairing of testing the reactive ability (response time) with performance success may be more valid than previous methods where only reactions to video projections were used.
Within this study, Hopwood et al. (2011) determined fielding response time using post-hoc frame-by-frame analysis at 25Hz. In order to validate the methodology used, a subset of 25 trials were captured using a high speed camera at 100 Hz. They found that the results obtained using the 25 Hz camera and the 100 Hz camera were comparable and therefore concluded that the 25 Hz camera was sensitive enough for movement time measurement.

### 2.7 Agility Training

As testing mechanisms of agility have recently been developed and refined in the literature, so too have the training methodologies employed for the improvement of agility. As it has been proven through testing studies that the perceptual-cognitive components of agility impact greatly on performance, more studies have begun to focus on training this cognitive component. As it has been shown that highly-skilled players exhibit faster and more efficient anticipation skills in comparison to lower-skilled players, research has begun to focus on the mechanisms in which this gap can be reduced, thus improving the anticipation skills of novices. It was always assumed that this increased ability was a result of longer exposure to specific reactive situations, however the use of technology is being tested for its ability to ‘fast-track’ this variable.

Farrow and Abernethy (2002) studied the effects of 4 weeks of video training on the ability to anticipate serve direction in tennis. Thirty-two schoolboy tennis players were split into four equal groups; explicit video training, implicit video training, control and placebo. The two video training groups viewed identical videos of a player serving the ball. The videos were filmed from a receiver’s perspective and included temporal occlusion. That is, the video is stopped at a set point in time in order to stop giving the viewer information. The participant had to select with a pen-and-paper response whether the ball was going to be
served to the left or right. The participant then watched the total unoccluded video. The difference between the video groups was that following the unoccluded video replay, the explicit group had specific service action variables highlighted to them. These variables included ball toss location, movement and angle of racquet, server’s grip, and stance and shoulder rotation, all of which impacted on potential serve location. The implicit video group did not receive any information regarding these service variables. The placebo group watched professional tennis matches and the control group completed physical training. Results after the 4 week training intervention indicated that the implicit video training group significantly improved their service direction anticipation whereas none of the other 3 groups improved. Intervention improvements were lost after a 32-day unfilled retention period.

Hopwood et al. (2011) studied the effects of a video training intervention on fielding performance in cricket. Using professional cricket players, pre-testing was completed using both a video-based anticipation test and a field-based test where the participant had to field balls. The training intervention involved half of the group watching video projections of batsmen striking the ball in their direction and the participant having to respond accordingly by moving in the appropriate direction. The training video included both occluded and unoccluded trials, meaning the participants would sometimes have to respond using advanced postural cues from the batsmen. Implicit learning strategies were used in that participants were not shown what to look for. The 6 week training intervention saw the video training group significantly outperform the control group within the video-based fielding test and showed greater improvements within the field-based test.
In the only rugby league based study, Serpell (2011) studied whether the perceptual and decision-making components of agility were trainable through video based training and whether this training resulted in an improvement in performance during a RAT. The training group completed reactive agility tests, which involved temporally occluded video projections with the participant required to move in the corresponding direction. Explicit based learning was used as participants were instructed to look at the hips, shoulder and trunk regions of the attacking players. It was found that the training group using video projections significantly improved their scores pre- to post-intervention and also significantly outperformed the non-training group. CODS tests did not show significant differences between the two groups. The training and testing videos also included feints, which showed that players are able to pick-up advanced kinematic clues in order to anticipate the direction in which the attacker will move (Serpell et al., 2011).

2.8 Implicit vs. Explicit Learning

Recently in the literature, studies have focused on whether anticipation skills can be improved by increasing a player’s advance cue utilisation. It has been hypothesised (Farrow & Abernethy, 2002) that by improving a player’s knowledge of postural cues and bodily orientation, the player will be able to respond faster and more accurately to the opposition in a real-life sport-specific setting. As a result, it is speculated that they will be able to anticipate the movements of their opponents earlier, and thus perform better on the field.

When using video training to improve anticipation, the type of learning is a variable that needs to be considered. Two broad types of learning exist regarding how information is gathered by the learner; these two types of learning are implicit and explicit.
Explicit learning, also referred to as conscious, selective and intentional learning, describes motor learning which “involves the use of specific instructions about how to develop a particular skill and concomitantly results in the acquisition of a large verbalizable knowledge base about how to perform the skill being acquired” (Farrow & Abernethy, 2002). In contrast, implicit learning, also referred to as unconscious, unselective, tacit and incidental learning, refers to “the acquisition of a motor skill without the concurrent acquisition of explicit knowledge about the performance of that skill” (Maxwell, Masters, & Eves, 2000). More simply, explicit training is when the individual is instructed on which specific cues to focus on to improve performance, whereas implicit training allows individuals to learn instinctively without outside instruction.

Studies in motor learning and skill acquisition have attempted to find the ideal mechanism for teaching new skills. Explicit learning has been used as an effective mechanism to highlight key contextual cues and relate this information to the subsequent outcome. For example, highlighting the racquet face angle may improve serve direction anticipation in tennis. The reasoning behind this theory is that explicit instruction contributes towards the cognitive knowledge base upon which perceptual knowledge is based (Williams & Grant, 1999). Despite this, in recent research implicit learning has been used extensively as it is proposed that implicit learning involves the acquisition of deep information about event sequence structure, which is not typically conveyed by explicit verbal instruction. It is also proposed that this deeper information encoding enhances information retention, which has been shown to be maintained longer than when information was learned via explicit instruction (Allen & Reber, 1980).
Additional studies have also proposed that learning implicitly increases the chance of skill retention under physically and mentally stressful situations (Masters, 1992). Masters (1992) tested golf putting accuracy amongst explicitly and implicitly trained participants. It was found that the implicitly trained group, who had no explicit knowledge of their acquired skill, performed better under a stressful situation compared to the explicitly trained group. It was proposed that the stressful situation interrupted the automated processing of information in the explicitly trained group.

Farrow et al. (2002) researched the anticipation of service direction amongst school-aged tennis players after explicit and implicit video training. In the experiment, the explicit video training group watched occluded video footage of an opponent serving the tennis ball. They were required to immediately predict whether the ball was to travel to the left or right side of the service box following the occlusion. They were then shown the same video i.e. the video was unoccluded. Information about the opponent’s body position and ball toss angle were highlighted in relation to the resultant serve direction. The implicit video training group viewed the same videos as the explicit group, however their task was to predict service speed following the video occlusion. Farrow et al. (2002) hypothesised that this task would indirectly improve a player’s ability to anticipate direction, as the kinematics of the server had to be closely monitored to anticipate service speed. After the speed prediction, the video was replayed without occlusion and showing the serve speed. No explicit instruction was given. It was found after the training intervention that the implicit video training group significantly improved their prediction accuracy whereas the explicit based video training group did not show any improvement. Following a 32-day retention period in which no training was performed, these training improvements dissipated. It is evident that additional studies focusing on the optimal learning approach in
relation to agility are needed in order to further understand the ideal mechanisms for training.

2.9 Rugby Football Warm-Up Protocols

Warming up for sports is completed for several purposes. The functions of a warm-up include preparing athletes for competition, preventing injuries, and developing athleticism and sport performance (Cone, 2007). Specifically, a warm-up should include two components: the physiological preparation for work and the physical preparation for movement demands of the sport (Cone, 2007). Warm-up protocols in rugby league also include skill-based activities, with positional specific tasks being completed, e.g. fullbacks fielding kicks, forwards braking tackles.

As it has been shown in the research that video training can improve performance on a reactive agility test, this may give rise to the notion that video training could potentially serve to benefit warm-up routines prior to a match. Previous research studying the ability of video-based training to improve the perceptual-cognitive component of agility performance has neglected to document the rate at which these improvements were achieved. These studies have predominantly measured the improvement of agility performance following a 4-6 week intervention period. Therefore, the rate of improvement in agility following video-based training remains unclear.

2.10 Summary of the Literature Review

The term agility has undergone a transformation over recent times within the literature, both in definition and application. Researchers have attempted to validate the optimal method of testing agility via addressing both the physical and cognitive demands of sport.
Testing studies have predominantly included the use of video projections with participants required to respond according to the video stimulus. These testing procedures have been able to discriminate high performance athletes from low performance athletes when changes of direction speed tests were unable to do so.

As a result of these testing studies, research has begun to focus on how to train athletes to anticipate more effectively in sport-specific settings. It has been hypothesised that improving an athlete’s ability to pick up and interpret postural cues from opponents will result in earlier responses and therefore faster movement times. This has been shown in cricket (Hopwood et al., 2011), rugby league (Serpell et al., 2011), tennis (Farrow & Abernethy, 2002) and Australian Rules football (Henry et al., 2011).

Training studies using video-based training protocols to improve anticipation have failed to measure the athlete’s improvement rate. These studies have primarily measured reactive performance improvement following a 4 to 6 week intervention period. However, the acute benefits of video-based reactive training are not evident in the literature. Further research is therefore justified.
Chapter 3 - Methodology

3.1 Participants

Thirty volunteer participants were recruited from the North Coast Under 15 and Under 17 Junior Gold Cup rugby playing squad. Participants were between fourteen and sixteen years of age (M= 14.6 years, SD = 1.09) at the commencement of the study. Additionally, all participants were required to have a minimum of two years as a registered player in junior rugby football sports (rugby league and/or rugby union). Volunteers were excluded from the study if they were suffering from any musculoskeletal injuries or if their health was not deemed sufficient to complete the study as determined by the completion of an Exercise and Sport Science Australia (ESSA) stage 1 pre-exercise screening questionnaire (see appendices).

3.2 Research Design

An intervention study was performed to assess the acute effects of a video-based warm-up on defensive performance of junior rugby football players. As part of the intervention, participants were assigned to one of three groups: implicit video group (IVG), explicit video group (EVG), or control group (CG). All three groups performed the same physical testing schedule, with the only difference being in the type of video intervention received. The research was granted ethical approval by the Southern Cross University Human Research Ethics Committee (ECN-12-277).
3.3 Intervention Groups

Participants were split into three groups for the intervention component of the study. All three groups viewed video clips within their intervention with the content differing between groups. The video clips for the implicit and explicit showed players running at the camera and executing a change of direction manoeuvre. The clips were filmed from the defender’s perspective and therefore represented what the defender would be exposed to in a game situation. Players from an amateur under-18 rugby league club were used as the attacking players in these clips; these players had no further involvement in the study. Junior amateur players were used in the video clips as their age and playing level were at a very similar level to that of the participants. This meant that the video stimuli presented within the video intervention closely resembled the stimuli available to the participant within the testing setting. This close link between the training and testing environments (in regards to the nature of the stimuli displayed) is vital to produce a positive transfer between the two settings. Using elite athletes within the video clips would not transfer to the testing setting as the type of movements completed would be different to those on display in the testing environment, where junior amateur players acted as the opponents. If the testing sample featured international representative players, players of a similar ability would be required to produce the videos in order to maintain the close link between the training and performance setting, and as a result promote a positive effect of the training intervention. The clips were filmed using an iPad (Apple ©, Version 2, IOS 7.0.4) and were edited using ‘Pinnacle Studio: Ultimate’ (Pinnacle Systems ©, Version 16) video editing software.
3.3.1 Implicit Video Group

Participants within the implicit video group viewed a series of video clips (16 different clips in total, each lasting approximately 20-25 seconds) of opposition players running and executing a change-of-direction manoeuvre i.e. step. Each individual video clip included three distinct components:

1. Video clip played in full speed (lasting approximately 5 seconds)
2. The same video clip played at half-speed (lasting approximately 10 seconds)
3. The insertion of a still image (at the end of the half-speed clip) of the opposition player at the initiation of the change-of-direction (as shown in Figure 3.1) (lasting approximately 7 seconds)

No kinematic or bodily orientation information from the trials was highlighted to the viewer during the still image. The entire intervention lasted approximately 7 minutes.

3.3.2 Explicit Video Group

The explicit video-based group viewed the same video clips as the implicit video group. Each individual video clip within the explicit videos lasted approximately 25-35 seconds. There were 16 video clips shown in total. These clips were longer than those shown to the implicit video group as the still image component contained explicit instructions. The components of each clip were:

1. Video clip played in full speed (lasting approximately 5 seconds)
2. The same video clip played at half-speed (lasting approximately 10 seconds)
3. The insertion of a still image (at the end of the half-speed clip) of the opposition player at the initiation of the change-of-direction, with key
kinematic cues, that serve as anticipatory information, highlighted in reference to future running direction (as shown in Figure 3.2) (lasting approximately 10-20 seconds)

The entire intervention lasted approximately 8 minutes.

In contrast to the implicit video group who received no explicit instruction, the participants within the explicit group had key postural cues, that could be used to anticipate movement direction, highlighted within the still image (Figure 3.2). This was done utilising arrows and joint angles being highlighted on the screen in addition to voiceover instructions. The explicit instructions (highlighting of joint angles and voiceover information) were completed by the researcher. The anticipation cues that were highlighted to the participants were adapted from previous literature that performed a biomechanical analysis of the strategies employed by attacking players in 1-v-1 rugby situations (Brault et al., 2010; Brault et al., 2012). This literature provided information regarding the postural orientation markers that can be used by a defender to anticipate movement direction. An example of the voiceover instructions provided to the explicit group during one of the video clips is shown below. The full transcript of voiceover instruction is provided in Appendix A.

Example of Explicit Voiceover Instruction: “The attacking player once again rotates the upper body and head in the opposite direction in an attempt to fool the defender. The hips however, which are an accurate predictor of future movement direction remain facing forward, thereby facilitating a change of direction to the right. This shows that an effective strategy of defensive anticipation is to focus on the hips rather than the upper body”.
3.3.3 Control Group

The control group viewed video highlights of an international rugby union match. This action was filmed from a side view (as is shown on television match broadcast). The footage did not provide any learning information to the participants. No learning cues or still images were shown to the participants. The game footage ran for the same amount of time as the videos shown within the intervention groups (approximately 8 minutes).

Figure 3.1: Example of Still Image as shown in Implicit Video Group
3.3.4 Experimental Group Matching

One of the primary objectives of the study was to compare the effectiveness of the different learning strategies on acute agility performance improvement via the video-based warm-up. In order to eliminate any potential confounding effects on the data, participants were sorted to their respective experimental groups based on their performance testing data. This meant that each group had an even proportion of physical abilities.

Participants were ranked (1-30; 1 being the top performer) based on their performance testing results. Participants received a ranking for 10m and 40m speed individually, which were combined to generate an overall rank which was used for group matching. For example, Person A came first (1) and seventh (7) on the 10m and 40m test respectively, giving them a combined score of 8 (1+7). Person B came twenty-first (21) and sixteenth...
(16) on the 10 and 40m test respectively, giving them a combined score of 37 (21+16). Athletes were then ranked on their combined score (i.e. the lower the combined score indicated the greater performance). The individuals were then placed in their respective experimental group in the following method: Rank 1 – Group 1, Rank 2 – Group 2, Rank 3 – Group 3, Rank 4 – Group 3, Rank 5 – Group 2, Rank 6 – Group 1, etc. The groups were then statistically compared using an analysis of variance (One-way ANOVA) test, to ensure there were no significant differences in baseline testing performance between the intervention groups that may have had a confounding effect on the results in the study.

### 3.4 1-v-1 Reactive Agility Test Protocol

The aim of the reactive agility test (RAT) was to assess participant’s response time in a sport-specific competitive setting. This RAT allowed for measurements to be taken in an ecologically valid environment. Previous studies researching the testing and training of agility have, almost exclusively, done so by having participants view life-size video projections of an opponent and challenging them to respond appropriately. This RAT protocol however employed a game specific 1-v-1 scenario, which allowed the defender’s response time to be recorded.

#### 3.4.1 Response Time

As discussed by Magill (2007), reaction time is defined as “the interval of time between the onset of a signal (stimulus) and the initiation of a response” (p. 25). Movement time (MT) is defined as “the interval of time between the initiation of a movement and the completion of the movement” (p. 25). Response time (RT) is the total time, thus incorporating both reaction time and movement time.
Within this study, response time was determined as being the time between the attacker’s outside foot (i.e. foot on opposite side to the direction of movement e.g. if the attacker moved to the right the outside foot was the left foot) leaving the ground and the defender’s outside foot leaving the ground. If the defender could apply effective anticipation skills and move in the correct direction prior to the attacker executing the ‘foot-off’ movement, the recorded response time would be negative. While this study uses the term ‘response time’, similar studies have used ‘decision time’ (Gabbett et al., 2008; Henry et al., 2011), ‘perception and response time’ (Serpell et al., 2011), ‘movement initiation time’ (Hopwood et al., 2011) to explain the same measurement.

The use of ‘foot-off’ as the start and end-point of response time was due to a number of reasons. An extensive search of the literature was conducted in order to find previous studies in which response time was quantified using kinematic data. Databases including SportDiscus, Scopus, Google Scholar, and PubMed were used within the search. The following keywords were used in various combinations within the above electronic databases: ‘kinematics’, ‘response time’, ‘reaction time’, ‘Vicon’, ‘biomechanics’, ‘anticipation’, ‘motion analysis’. Of the returned articles, none provided any kinematical explanation of response time in an open environment. The majority of articles with the focus of studying response/reaction time quantified such qualities via the pushing of a button, the use of a force platform, etc. The articles with a focus on producing valid tests of anticipation in response to a stimulus did so by employing videos of sport-specific stimuli which the participant had to respond to. High-speed videos were then used to determine the first movement in the correct direction (Farrow, Young, et al., 2005). This was difficult to use for the current study as the defender within this study may make a multitude of movements in both directions prior to finally committing to the final
direction. This was in part due to the fact that there was a greater level of uncertainty in terms of the spatial and temporal constraints within our 1-v-1 RAT in comparison to other studies using video information. In addition, it was also in part due to the fact that the defender was already in motion when they execute their response.

3.4.2 Test Setup

The RAT area was a rectangle measuring 9m x 6m. Two centre gates, 2m wide, were setup on either side of the testing area 3.5m from the attacker and defender (shown by the triangle markings in Figure 3.3). The area was designated with marker cones and free of any loose debris prior to testing to ensure participant safety.

Figure 3.3: 1-v-1 RAT Set Up (DEF = Defender, ATT = Attacker, \(\Delta\) = Centre Gate Markers)
3.4.3 Test Protocol

At the beginning of the test, both the attacker and the defender were situated at their respective starting points, at the centre of each end of the test area, directly opposite and separated by 9 metres. The attacking player’s role was to run forward and then in their own time perform a side step to the left or right and pass through one of the centre gates (shown by triangle markings in Figure 3.3). The defending player’s goal was to move forward and react to the attacking player by moving through the same centre gate as the attacker, e.g. if the attacker stepped to his left and thus moved through the left centre gate, the defender was to quickly move through this gate also (although the defender would have to move to their right). In the performance setting, defenders often position themselves in a manner to force the attacker to move in a specific direction beneficial to the defending team, often towards the sideline or additional defenders. Within this task however, the defender was not instructed or permitted to utilise these tactics of cutting off one side of the testing area to force the attacker to move to the opposite direction. They were instructed to move forwards toward the attacker and accelerate toward the appropriate gate after anticipating or reacting to the attacker’s movements. The attacker, who completed the test whilst holding a rugby union ball (Gilbert match size) were instructed to attempt to eliminate the defending player as they would in a game situation. This meant that the attackers were permitted to employ feint techniques and deceptive manoeuvres in an effort to make the defender go the wrong way (i.e. ‘wrong-foot’ the defender). A trial on the 1-v-1 RAT test was completed when both the attacker and the defender passed through the same centre gate.
3.4.4 Data Collection

3.4.4.1 3D Motion Analysis System Setup

Data from each trial was collected through the use of a three-dimensional motion analysis system, Vicon MX (Oxford Metrics, Oxford, UK). This capture system tracked the movement of light reflective markers, located on the participants, which was later analysed to determine when the defender moved in the appropriate direction, thus allowing the researcher to quantify response time. The reliability of the VICON 3D motion analysis system has been shown to provide reliable data in the detection of movement (Chung & Ng, 2012).

System preparation for the testing sessions began approximately two hours prior to the participants’ arrival. Following the designation of the test protocol area with marker cones,
twenty 3D motion capture cameras (Vicon T-Series), were set up around the outside of the test area (indicated by coloured circles in Figure 3.5).

Following the placement of the cameras to surround the 1-v-1 RAT testing area, each camera was individually connected to the Giganet (camera input that connected to the computer) via cabling that allowed for the motion analysis system to be operated through the Vicon Nexus Software (Version 1.8.4). Reflective markers were then placed within the ‘capture zone’ to allow for the manual adjustment of the cameras. Each camera was directed at a particular segment of the capture zone so that the entire area was covered by the twenty camera setup. As shown in Figure 3.6, the cameras indicated by green circles were primarily focused on the attacker’s movement area, while the cameras indicated by the red circles were primarily focused on the defenders end of the testing area. The middle
cameras, indicated by blue circles, were focused on the middle segment of the testing area. This testing setup ensured all movement within the 1-v-1 RAT test area was seen and recorded by the cameras.

Using the Vicon Nexus software, the 3D motion analysis system was then calibrated for testing. First, the strobe intensity (level of camera LED intensity) was reduced so that only the reflective markers were recorded by the system and any additional reflections that would have impacted on the data capture were excluded. The cameras were adjusted to record data at 100 frames per second. A dynamic calibration was then performed and the reference point was set. The system was then ready for testing.

3.4.4.2 Participant Preparation

Upon arrival and prior to the completion of the warm-up, participants had light-reflective markers attached. Each participant had three light-reflective markers attached to their foot at the toe (third metatarsal), ankle (lateral malleolus), and heel (calcaneus) on both the left and right legs (see Figure 3.6). Markers were secured with double-sided tape and sports tape.

A static calibration was then performed on each participant. Each participant stood in the capture zone which was recorded by the 3D motion analysis system. Using this recording, the software could produce an individualised model of each participant’s foot segment that was applied in the testing trials. Following the static calibration, the system was fully prepared for testing.
3.4.5 Testing Environment

Participants attended three testing sessions which were all held at the Southern Cross University, Lismore Campus. The sessions were all held at a similar time of the day in the late afternoon/early evening. The 1-v-1 RAT test was completed on an indoor basketball court with a wooden floor. Performing the testing on the wooden surface could be considered to lack ecological validity (as football sports are played on outdoor grass fields), however testing indoors eliminated problems that may have arisen from damage to the testing area following multiple trials. Additionally, as testing was completed over multiple days, using the indoor environment eliminated weather variables that could have impacted upon the study. Participants wore training standard running shoes with appropriate non-slip grip. In addition they wore training shorts and a t-shirt. The testing area was cleaned of dust and debris prior to each testing session.
3.5 Testing Schedule

Table 3.1 – Testing Schedule

<table>
<thead>
<tr>
<th>Familiarisation Session</th>
<th>Session One</th>
<th>Session Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. General Warm-up</td>
<td>1. General Warm-up</td>
<td>1. General Warm-up</td>
</tr>
<tr>
<td>2. Performance Testing</td>
<td>2. ‘Pre’ 1-v-1 RAT (5 trials)</td>
<td>2. ‘Pre’ 1-v-1 RAT (5 trials)</td>
</tr>
<tr>
<td>b. 10m Acceleration</td>
<td>a. Implicit</td>
<td>a. Implicit</td>
</tr>
<tr>
<td>c. 40m Speed</td>
<td>b. Explicit</td>
<td>b. Explicit</td>
</tr>
<tr>
<td>3. Test Familiarisation</td>
<td>c. Control</td>
<td>c. Control</td>
</tr>
<tr>
<td></td>
<td>4. Brief Warm-up</td>
<td>4. Brief Warm-up</td>
</tr>
<tr>
<td></td>
<td>5. ‘Post 1-v-1 RAT (5 trials)</td>
<td>5. ‘Post 1-v-1 RAT (5 trials)</td>
</tr>
</tbody>
</table>

3.5.1 Familiarisation Session

Prior to the performance testing within the familiarisation session, an information session lasting approximately twenty minutes was held to explain the study to the potential volunteers. Participants were given clear information regarding exactly what they were to do if they chose to be a volunteer and the risks and benefits associated with participation. Following this information, those who were interested in becoming a participant of the study were provided with an information sheet and asked to complete an informed consent form; this required parent/guardian approval and signature. Participants were also required to complete a standard health pre-screening questionnaire (see Appendices B, C, D and E).

Following the information component, participants performed baseline performance tests. Tests were selected to assess 10m linear acceleration, 40m linear speed and body measurements (height, mass). Following the completion of the performance testing,
participants were shown the protocol for the 1-v-1 RAT protocol in order to gain familiarity with the protocol prior to testing in session two. Participants then performed three practice trials of the 1-v-1 RAT to gain test familiarity.

3.5.1.1 Anthropometry Measurements

Prior to the physical performance tests, the participants had their height and body mass determined. Participant’s height was assessed using a wall stadiometer, with the participant’s body mass determined using digital body composition scales (Tanita, Australia).

3.5.1.2 Linear Speed and Acceleration

A 40m linear speed test was performed to assess participants speed performance. During this test, a split time at ten metres was used to assess acceleration. Participants began in a self-selected semi-crouch position and began the test at their own volition. The participants were instructed to accelerate through the final light gate in order to avoid any measurement error garnered by decelerating prior to the final gate. The ‘Speedlight V2’ light gate system (Swift Performance, Wacol, QLD) was used for the timing of the test. Two trials were performed by each participant and the best 10m and 40m time was used for analysis.

3.5.1.3 Testing Subgroups

For the purposes of data collection sessions one and two, the 30 participants were placed into 5 testing subgroups. Each subgroup had 6 participants, except for subgroups 2 and 4 who had 5 and 7 participants, respectively (these groups had a different number of participants due to participant availability). Participants were randomly allocated into these testing subgroups. Testing subgroups were irrespective of the experimental groups in that each subgroup did not have an even distribution of experimental group participants. As
each participant completed 10 trials (8 and 12 trials for groups 2 and 4, respectively) of the 1-v-1 RAT test (five prior to the intervention and five following the intervention), this meant that each defender competed against each other participant within their group once before and once after the intervention. After the participants were allocated into testing subgroups, these groups were statistically analysed using a one-way general linear model to ensure that no differences within the performance test results existed between subgroups which could have affected potential results. This analysis showed no differences between groups based on 10m ($p = 0.354$) or 40m speed ($p = 0.579$), and thus testing could commence using these subgroups.

### 3.5.2 Data Collection - Session One

Following a one week break, participants returned to complete the data session one of the data collection. This was the first session in which the participants completed the 1-v-1 RAT. Participants arrived and first completed a general body warm-up (shown below) which was standardized for all participants and led by the lead researcher. The participants were then required to complete their first five trials of the 1-v-1 RAT. This meant that each person within the six person group performed five trials, with each against a different defender. Following the completion of the pre-testing RAT, participants split into their intervention groups and viewed the corresponding video footage. Following the intervention break to watch the videos, which lasted approximately eight minutes, participants returned to the testing area and performed a brief warm-up to negate any effects of sitting down for the intervention period. Following this brief warm-up, participants completed an additional five trials of the 1-v-1 RAT with the same group members, which made up the post-testing element of the protocol.
3.5.2.1 General Warm-up

Upon arrival at the testing location, the lead researcher took the participants through a standardized warm-up routine lasting approximately 9 minutes. The warm-up was as follows:

1. Low/medium intensity jogging (3mins)
2. Dynamic stretching – hamstring stretches, lunges, etc. (2mins)
3. Dynamic warm-up – side shuffling, butt kicks, high knees, agility ladder (2mins)
4. Participants with self-perceived tight muscles were permitted additional stretching (2mins)

3.5.2.2 1-v-1 Reactive Agility Protocol

After completing the general warm-up, each participant was given two practice trials of the 1-v-1 RAT. Following this, participants began the first component of the testing protocol, performing five trials as the defender. Each trial (lasting approx. 3 seconds) was separated by at least 30 seconds, which provided a work: rest ratio of at least 1:10, which is deemed significant to sufficiently restore ATP production (McArdle, Katch, & Katch, 2010). The participants also acted as attacking player’s; however, this did not impact upon their rest time as sufficient time between trials was provided on each occasion. Following the intervention period and subsequent brief warm-up, participants returned and completed the remaining five trials of the 1-v-1 RAT.

3.5.2.3 Intervention

After the pre-testing component of the session, participants completed the intervention component of the study. Participants viewed their video on a laptop computer and were isolated from each other while they viewed the video corresponding to their group.
Additionally, participants listened to the video’s audio through headphones provided by the researcher (see Figure 3.7).

![Figure 3.7: Athletes watched their respective videos on laptops with headphones](image)

3.5.2.4 **Brief Warm-up**

After returning from the intervention period, which lasted approximately eight minutes, athletes completed a brief series of ‘run-through’ drills in order to negate any of the effects of sitting down for the previous study component. These drills ensured that participants were physically prepared for the post-testing component and the chance of injury was limited. Following this brief warm-up, the participants completed the post testing component of the testing session. This included the additional five trials which assessed the impact of the intervention. The process of data collection following the intervention was completed in an identical method to the pre-intervention testing.
3.5.3 Data Collection - Session Two

Session two of data collection was a replication of session one, utilising exactly the same protocol. Participants remained in the same intervention groups and testing groups and thus viewed the same videos as they did in session one as part of the intervention component. This session was to test for a learning effect of the testing protocol and to further assess reliability of the testing protocol. Session two was conducted seven days after session one. Table 3.1 summarises the format of testing.

3.6 Statistical Analysis

3.6.1 Data Treatment

Each participant performed five trials pre-intervention and five trials post-intervention. A ‘trimmed mean’ was used in that each participant’s fastest and slowest scores were disregarded and the mean was taken of the three remaining scores. This method allowed for the removal of any outliers and reduced the likelihood of Type 1 error because of largely fluctuating data (Keselman, Kowalchuk, Algina, Lix, & Wilcox, 2000). This score was then used for the purpose of statistical analysis.

3.6.2 Analysis of Data

All statistical analyses were performed using the statistical analysis software, SPSS (IBM© SPSS© Statistics, Version 22). To examine the acute effects of a video-based warm-up on response time and agility, the mean scores of the response time from the three groups (Explicit, Implicit and Control) in pre and post-tests during session one were compared using a general linear model (GLM) with repeated measures analysis, with two-way interactions of intervention group (three groups) by testing occasion (pre, post). Only the scores from session one were used in the analysis as the purpose of the study was to
determine if the video-based warm-up protocol could facilitate an acute effect on sport-specific response time. The inclusion of session two data would have meant that the participants were exposed to the video-based warm-up on two separate occasions and this would have resulted in a training effect rather than the acute warm-up effect. The purpose of session two was to assess the reliability of the testing protocol. Statistical significance level was set at an alpha level (P) of ≤ 0.05.

If a significant main effect and interaction were identified, post-hoc comparisons with a Bonferroni adjustment were used to determine where the differences were located. Effect sizes for the difference between the means were calculated with descriptors of “trivial” (0.0-0.19), “small” (0.2-0.59), “moderate” (0.6-1.19) and “large” (1.2-1.9) (Batterham & Hopkins, 2006)

As the 1-v-1 RAT was a new testing procedure not previously used in the literature, a statistical analysis was performed in order to assess the testing protocol’s reliability. Pre-intervention response times from session one were statistically compared with the pre-intervention response times from session two, using an intraclass correlation coefficient (ICC) analysis. In addition, a general linear model with repeated measures was conducted with two-way interactions of intervention group (three groups) and session (session one and session two). The standard error of measurement (SEM) (Atkinson & Nevill, 1998) and 95% confidence intervals were also calculated for both sessions.

A bivariate Pearson’s product-movement correlation coefficient (r) was calculated for the relationship between each of the response time, performance testing measures and descriptive data variables. A participant’s age was measured in years and months for the purpose of analysis.
Chapter 4 - Results

4.1 Participant Descriptive Statistics & Performance Testing

Prior to performing the 1-v-1 reactive agility testing, participants were split into the three testing groups based on performance testing (10m linear acceleration and 40m linear speed) results. A one-way analysis of variance was performed to assess if there were any pre-testing differences between the groups. There were no significant differences in performance testing results or physical characteristics between the three testing groups, as shown in Table 4.1. The physical characteristics and performance testing data for each group, in addition to the significance level of between group analyses is shown in table 4.1.

Table 4.1: Participant Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>EVG (n=10)</th>
<th>IVG (n=10)</th>
<th>CG (n=10)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>14.8 ± 1.1</td>
<td>14.5 ± 1.2</td>
<td>14.5 ± 0.9</td>
<td>0.782</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.0 ± 11.7</td>
<td>71.7 ± 10.8</td>
<td>79.1 ± 18.0</td>
<td>0.508</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.1 ± 8.1</td>
<td>175.1 ± 7.1</td>
<td>177.5 ± 9.0</td>
<td>0.861</td>
</tr>
<tr>
<td>10m Speed (secs)</td>
<td>1.87 ± 0.08</td>
<td>1.82 ± 0.08</td>
<td>1.89 ± 0.13</td>
<td>0.354</td>
</tr>
<tr>
<td>40m Speed (secs)</td>
<td>5.98 ± 0.35</td>
<td>5.81 ± 0.35</td>
<td>6.03 ± 0.48</td>
<td>0.579</td>
</tr>
</tbody>
</table>

*Note: EVG = Explicit Video Group   IVG = Implicit Video Group   CG = Control Group
4.2 Pre- to Post-Intervention Response Time Effects

The results of the 1-v-1 RAT testing were examined using a two-way general linear model with repeated measures analysis for session one. Mean response time improved from pre-intervention (M = 0.251s) to post-intervention (M = 0.217s) by 0.034 seconds (s). This represented a relative change of 9.4%. This represented a significant difference in the main effect of testing occasion (response time from pre- to post-intervention), $F (1, 25) = 7.396, p = .012$. By further examining the statistical analysis, it was determined that there was no significant interaction of testing occasion and intervention group, $F (2, 25) = 0.789, p = .465$.

Although no significant interaction may indicate the trend of change was similar among the three groups, there may have been a significant change within a group from the effect of intervention as a significant main effect of test occasion (pre, post) was detected. Therefore, post-hoc comparisons with a Bonferroni adjustment were used to examine the response time changes for each group individually. The explicit video group’s mean pre-intervention response time was 0.246 s, which decreased to 0.199 s at post-intervention. This reduction of 0.047 s (19.1%) was statistically significant, $F (1, 25) = 5.265, p = .030$.

The implicit video group’s mean pre-intervention response time was 0.268s, which decreased to 0.226 s. This reduction of 0.042 s (15.7%) was statistically significant, $F (1, 25) = 4.299, p = .049$. The control group’s mean pre-intervention and post-intervention times were 0.238 s and 0.227 s respectively. This was a mean reduction of 0.011 s (4.6%) which was not statistically significant $F (1, 25) = 0.299, p = .367$. The intervention results are shown in table 4.2 and figure 4.1 (for raw data see appendix).
Table 4.2: Pre- and Post-Intervention Performance on the 1-v-1 RAT

<table>
<thead>
<tr>
<th></th>
<th>Pre-Intervention Mean ± SD (s)</th>
<th>Post-Intervention Mean ± SD (s)</th>
<th>Performance Change Mean ± SD (s)</th>
<th>Relative Change (%)</th>
<th>Numerator df</th>
<th>Denominator df</th>
<th>P Value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVG</td>
<td>0.246 ± 0.07</td>
<td>0.199 ± 0.09</td>
<td>0.047* ± 0.13</td>
<td>19.1%</td>
<td>1</td>
<td>25</td>
<td>0.030</td>
<td>0.28 (Small)</td>
</tr>
<tr>
<td>IVG</td>
<td>0.268 ± 0.06</td>
<td>0.226 ± 0.06</td>
<td>0.042* ± 0.15</td>
<td>15.7%</td>
<td>1</td>
<td>25</td>
<td>0.049</td>
<td>0.33 (Small)</td>
</tr>
<tr>
<td>CG</td>
<td>0.238 ± 0.08</td>
<td>0.227 ± 0.06</td>
<td>0.011 ± 0.15</td>
<td>4.6%</td>
<td>1</td>
<td>25</td>
<td>0.367</td>
<td>0.08 (Trivial)</td>
</tr>
</tbody>
</table>

* = denotes significant performance change from pre- to post-intervention (p < 0.05)
Explicit Video Group (EVG), Implicit Video Group (IVG), Control Group (CG).
4.3 1-v-1 RAT Testing Protocol Reliability

Test-retest reliability was examined using an intraclass correlation coefficients (ICC) analysis. This reliability analysis included each participant’s average response times from pre-intervention testing during session one and session two. The intraclass correlation coefficient for average measures was 0.638 (Table 4.3). It has been suggested in the literature that this result may be described as being of ‘moderate’ reliability (Portney & Watkins, 1993). To further assess the reliability of the testing protocol, the standard error of measurement (SEM) was calculated. The SEM for sessions one and two was 0.040 (CV = 16%) and 0.045 s (CV = 19.9%), respectively. By using this data, the 95% confidence interval was determined to be 0.252 ± 0.078 for session one and 0.223 ± 0.088 for session two.

Figure 4.1: Pre- and Post-Intervention Performance on 1-v-1 RAT
The differences between session one and session two on the 1-v-1 RAT protocol were examined using a two-way general linear model with repeated measures for pre-intervention data for both sessions. The mean response time for session one and session two was 0.252 and 0.227 s, respectively. This represented an overall change of 0.024s and a relative change of 9.9%. This change was not significant, $F(1, 25) = 2.654, p = .116$.

Table 4.3: Intraclass Correlation Coefficient (ICC) Results

![Intraclass Correlation Coefficient Table]

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.
b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Figure 4.2: Comparison of Session 1 and Session 2
Table 4.4: Comparison of Session One and Session Two on the 1-v-1 RAT

<table>
<thead>
<tr>
<th>Group</th>
<th>Session One Mean ± SD (s)</th>
<th>Session Two Mean ± SD (s)</th>
<th>Performance Change Mean ± SD (s)</th>
<th>Relative Change (%)</th>
<th>Numerator df</th>
<th>Denominator df</th>
<th>P Value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVG</td>
<td>0.246 ± 0.07</td>
<td>0.211 ± 0.04</td>
<td>0.035 ± 0.08</td>
<td>14.2%</td>
<td>1</td>
<td>25</td>
<td>0.152</td>
<td>0.29 (Small)</td>
</tr>
<tr>
<td>IVG</td>
<td>0.268 ± 0.06</td>
<td>0.236 ± 0.09</td>
<td>0.032 ± 0.06</td>
<td>11.9%</td>
<td>1</td>
<td>25</td>
<td>0.190</td>
<td>0.20 (Small)</td>
</tr>
<tr>
<td>CG</td>
<td>0.238 ± 0.07</td>
<td>0.235 ± 0.08</td>
<td>0.003 ± 0.07</td>
<td>1.3%</td>
<td>1</td>
<td>25</td>
<td>0.920</td>
<td>0.02 (Trivial)</td>
</tr>
</tbody>
</table>

Explicit Video Group (EVG), Implicit Video Group (IVG), Control Group (CG).
4.4 Performance Testing and 1-v-1 RAT Correlations

To assess the size and direction of the linear relationship between participants’ response time (RT) as part of the 1-v-1 RAT, the performance tests and the participant’s descriptive characteristics, a bivariate Pearson’s product-movement correlation coefficient ($r$) was calculated. The Pearson’s correlation results are provided in table 4.5.

Response Time was not significantly related to any of the performance test variables or physical characteristics. Of the correlations performed between the performance test and descriptive characteristics variables, a significant correlation existed between Age and 40m, $r(28) = -0.451$, $p = 0.24$, and between 10m and 40m speed, $r(23) = 0.881$, $p = 0.00$.

Table 4.5: Pearson Correlations Coefficients between Response Time, Performance Tests and Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>RT</th>
<th>10m</th>
<th>40m</th>
<th>Age</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>1</td>
<td>-0.20</td>
<td>0.088</td>
<td>-0.144</td>
<td>0.83</td>
</tr>
<tr>
<td>10m</td>
<td>-0.20</td>
<td>1</td>
<td>0.887*</td>
<td>-0.318</td>
<td>0.180</td>
</tr>
<tr>
<td>40m</td>
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<td>0.887*</td>
<td>1</td>
<td>-0.451**</td>
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<td>0.180</td>
<td>0.256</td>
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* = denotes significance ($p = 0.00$), ** = denotes significance ($p = 0.24$)
Chapter 5 - Discussion

This project was developed in an attempt to add to the body of knowledge in the area of agility. More specifically, the aims of this study were to: i) to investigate the use and reliability of a 3D motion analysis system as a new method for quantifying response time, ii) determine the acute effects of a video-based warm-up on performance during a rugby football specific reactive agility test; and iii) to investigate the difference between implicit and explicit video-based warm-ups in relation to their benefit on performance in a rugby football-based RAT.

Explicit-based and implicit-based video warm-up protocols were implemented and compared for their acute effect on response time. In contrast to other studies on agility that have used video screens and illuminating lights as the stimulus, this study attempted to test agility in an environment more ecologically representative of the performance setting. To achieve this, 3D motion analysis was implemented to quantify response time during a novel 1-v-1 testing protocol.

The main findings of this study were that there was a reduction in mean response time from pre-to-post video warm-up intervention period without a significant interaction between groups. Post-hoc analysis of the main effect revealed that both the implicit and explicit video groups significantly improved their response times whereas the control group remained relatively stable. There was no significant difference in the level of improvement between the implicit and explicit video groups. An analysis of the novel 1-v-1 test methodology, assessed using 3D motion analysis, indicated moderate reliability.
5.1 Reliability of the Testing Protocol

Reliability of the testing protocol was assessed by completing the testing on two separate occasions, one week apart. To assess reliability, the scores from the pre-intervention of session one were statistically compared to the pre-intervention scores of session two. Only using the pre-intervention scores allowed the testing protocol to be assessed for reliability without the cofounding effect of the video-based warm-up. The intraclass correlation coefficient (ICC) of 0.638 indicated ‘moderate’ reliability (Portney & Watkins, 1993). This indicated that the testing battery, with the use of a 3D motion analysis system as the measurement device, is a valid method of quantifying sport-specific response time. The standard error of measurement (SEM) for session’s one and two was 0.040 (CV = 16%) and 0.045 s (CV = 19.9%), respectively. By using this data, the 95% confidence interval was determined to be 0.252 s ± 0.078 s for session one and 0.223 s ± 0.088 s for session two.

The ICC is sensitive to the degree of between-subject variability, i.e. the larger the between-subject variability the larger the ICC (Vincent & Weir, 2012). The ICC achieved represented moderate reliability of the testing protocol however, between-subject variability may have influenced this result. While the participants used for testing were all from the same representative squad and age group, differences in the level of perceptual-cognitive ability amongst the sample may have resulted in a large variance of results achieved on the testing protocol. This would therefore have influenced the reliability results. The SEM and confidence intervals are calculated using the results of the ICC, and therefore are indirectly affected by the between-subjects variability (Vincent & Weir,
2012). The level of reliability achieved may therefore, be a result of the high variance between subjects and a relatively small sample size.

The difference between pre-intervention data from the two sessions was also compared using a general linear model with repeated measures. The results indicated no significant change in scores between the two sessions. Scores however from the two experimental groups (explicit- and implicit-video) indicated that the pre-intervention scores from session two were improved from those recorded in session one, while the control groups scores remained unchanged (see Figure 4.2). This indicated that the acute effect facilitated by the video-based warm-up intervention in session one was retained for the following weeks testing. This may indicate that the completion of an isolated video-based warm-up protocol may facilitate an improvement in sport-specific response time over a week’s period.

5.2 Correlations between Response Time and Performance Tests

By performing performance tests prior to testing, including the 10m and 40m speed tests, correlations between these markers of performance and the response times achieved through the 1-v-1 reactive agility test could be determined. Our results showed that there were no significant correlations between either of the performance testing results and that of response time. This result confirms the findings of earlier research that made comparisons between agility performance and physical measures. These studies (Farrow, Young, et al., 2005; Henry et al., 2011; Serpell et al., 2010) found no correlation between the results of performance of physical testing and performance testing with a reactive element. Our results also showed that high performers within the performance testing were not necessarily the high performers on the 1-v-1 RAT; therefore the protocols were measuring separate qualities and abilities.
5.3 Effectiveness of the Video Warm-up on Response Time

A major finding of this study was that there was a significant main effect of response time from pre-intervention to post-intervention testing. Following the statistical analysis, it was found that the mean response time of the cohort dropped from 0.251 seconds (s) during the pre-intervention (pre video warm-up) stage to 0.217 s at the post-intervention (post video warm-up) testing. This reduction of 0.034 s represented a relative change of 9.4%. This change represented a significant main effect (p = 0.012).

The data obtained for response time was similar to other studies quantifying a response time/decision time within sport-specific agility testing. Gabbett and Abernethy (2013), in quantifying response time of under-16 rugby league athletes using 2D video projections of a sport-specific stimulus, obtained mean response times of around 0.21 and 0.26 seconds for the high skilled and intermediate skilled groups respectively (Gabbett & Abernethy, 2013). Henry et al. (2011) reported a mean response time of 0.31 s in response to a 2D video-based sport-specific stimulus for high-performance Australian Rules football players.

Our results also reflected previous research that found improvements in response time following training intervention periods. Serpell (2011) found mean response times of rugby league players responding to 2D projections of 0.34 s pre-training and 0.04 s post-training, therefore registering a training-induced improvement of 0.30 s and a relative change of 88%. Hopwood (2011) also delivered an improvement in ‘mean movement initiation time’ (time from stimulus onset to the responder beginning the execution of their response) following a training intervention within cricketing fielding. Pre-training the athletes’ mean response time was 0.247 s, which was reduced to 0.221 s following the
training intervention. The intervention therefore elicited a reduction of 0.026 s and a relative change of 11%.

In comparing our results to those obtained by Serpell et al. (2011), a number of similarities and contrasts within the methodology and reported outcomes can be drawn. Within Serpell’s (2011) study, they achieved an 88% relative reduction in mean response time from pre- to post-training intervention. This was in comparison to the 9% reduction within this study. This may, as a result, demonstrate the value in a longer training intervention. Within the current study the objective was to assess the acute effect of a video warm-up and therefore the athletes were not exposed to the length of training provided in the Serpell et al. (2011) study. Serpell’s (2011) study had the athletes complete two sessions per week for three weeks, with each session lasting fifteen minutes. This resulted in a total training time of approximately ninety minutes. Therefore, the athletes within the study received an additional 900% of training time over the athletes used within the current study, who only completed a single ten minute intervention. This may in some way explain the additional improvement received within their research. Therefore, a video-based warm-up may deliver an acute effect on subsequent reactive performance; however greater gains in perceptual-cognitive ability may require a longer training intervention.

A further consideration that may have impacted on the achieved results was the link between the perception and action cycles within the training intervention, used within previous studies but absent within this current study. It has been suggested in the literature (Farrow & Abernethy, 2003) that “perception and action” must be combined within the training setting in order to transfer to the performance setting, as the training of the perceptual component alone does not trigger the same motor learning patterns as when the
two are combined. In summarising Milner and Goodale (1995), Farrow and Abernethy (2003) explained that “the ‘vision for perception’ ventral stream delivers information about the characteristics of objects and their relations for the purpose of perceptual identification and classification, where in contrast, the ‘vision for action’ dorsal stream mediates the online visual control of selected actions” (p.1128). Using this theory, tasks in the performance setting require the use of both streams to allow for the optimal response to stimuli. Further research found no significant differences between the improvements made between groups with and without perception-action coupling (Williams, Ward, Smeeton, & Allen, 2004). Williams, Ward, et al. (2004) concluded that: “anticipation skill can be improved through appropriate instruction regardless of whether the learner has to physically respond to the action or merely make a perceptual judgment” (p. 358). Williams, Ward, et al. (2004) further suggested that reading an opponent’s intentions through postural cues may in fact rely more on the ventral process and therefore, the decoupling of the two processes may be inconsequential. It may be the case that the coupling is only required in tasks that require the “direct mapping of perceptual variables onto various action parameters” (p. 359) for example striking a cricket ball (Williams, Ward, et al., 2004).

Both Serpell et al. (2011) and Hopwood et al. (2011) maintained the link between perception and action within their training modalities and achieved an increase in response time performance during the post-testing. This coupling of perception and action within the training methodology was absent within the current study. Uncoupling of the perception and action streams was done on purpose as a significant finding may have resulted in the implication that athletes could utilise this training methodology during recovery/non-training days with limited energy expenditure, minimal coaching and
equipment requirements. This would therefore offer a substantial practical application to the field. Even though the video-warm-up intervention did facilitate an effect on subsequent testing, the lack of coupling between the dorsal and ventral pathways may have had an effect on the level of improvement. However, using the theory posited by Williams, Ward, et al. (2004), the nature of the task, which was reliant upon reading an opponent’s intentions through postural cues, suggests that the uncoupling of perception and action would not have had an effect upon the results.

5.4 Effect of Learning Strategy on Response Time

The secondary purpose of the current study was to determine whether the type of learning strategy employed within the video-based warm-up had an impact on the acute effect to reactive performance. More specifically, the aim was to examine the difference between implicit and explicit video-based warm-ups in relation to their benefit to performance in a rugby football-based reactive agility test.

Within the literature, both implicit and explicit-based learning strategies have been endorsed as being effective in producing adaptations to anticipation skills. While explicit strategies have been recommended as an effective avenue to increasing initial declarative knowledge that aids in response selection (Anderson, 1982), implicit learning strategies have been promoted as they may produce improvements that are more robust over time and during stressful situations (Masters, 1992). It has also been suggested that explicit instructions place a heavy cognitive load upon athletes that may interfere with the proceduralisation of the task (Green & Flowers, 1991), strengthening the argument for implicit-based learning.
Within the current study, a significant improvement in response time from pre- to post-intervention was found. No significant interaction was found however between the three groups (explicit, implicit, and control). By examining the significant main effect further, through post-hoc analyses, it was found that both the explicit and implicit group significantly improved their mean response time from pre- to post-intervention, while the control group did not. Therefore, due to the absence of a significant interaction the research hypothesis, (that the experimental groups (explicit- and implicit-based groups) would reduce their response time more than the control group, cannot be accepted with confidence. However the significant post-hoc analyses suggest a strong effect of the implicit and explicit video protocol on improving subsequent agility performance. In addition, as there was no significant difference between the levels of improvement between the two experimental groups, the secondary hypothesis, that there would be no significant differences in response time improvement between the implicit and explicit video-based warm-up groups, is accepted. These results suggest, if only within the current study, that both explicit and implicit instruction are valid learning strategies to increase acute agility performance.

The results of the current study are in line with the results obtained in previous studies that compared different types of learning strategies within anticipation training protocols. Williams et al. (2002) compared the effects of different learning strategies in regard to their ability to facilitate an improvement in tennis-specific anticipation. Specifically, the study compared the effectiveness of an explicit, guided discovery, placebo, and control group in regard to their anticipation ability pre- and post-training. Both the explicit and guided discovery group improved their decision time, whereas the placebo and control groups did not. There were no differences between the explicit and guided discovery
groups (Williams, Ward, Knowles, & Smeeton, 2002). Smeeton et al. (2005) also compared the effectiveness of an explicit, guided discovery, and discovery learning based groups in their ability to improve tennis anticipation over a four week training intervention. The results again reflected those found in the current study, in that the experimental groups improved their decision time from pre- to post-training while the control group did not (Smeeton et al., 2005).

An obvious contrast between the two aforementioned studies and the current study is that the previous studies compared the effectiveness of an explicit-based protocol and a guided discovery protocol, while the current study compared an explicit group and a purely implicit, also termed ‘pure discovery’, group. The guided discovery approach, as used in previous studies, includes the highlighting of general areas for anticipatory cues to be obtained without providing the viewer any rules regarding their anticipatory context. Filming an opposition player within rugby football sports performing an evasive manoeuvre and instructing the viewer to simply “look at the hip region”, would be an example of utilising the guided discovery approach. The implicit-based learning strategy applied within the current study was a ‘pure discovery’ approach in that no instruction or feedback was provided to the viewer. This strategy replicated the learning that is often allowed for within small-sided games and similar sporting warm-ups that do not include specific instructions for anticipation. This allowed for the researchers to draw comparisons between the explicit approach, where the athletes were instructed on where to focus their attention and had associations between anticipatory cues and the resultant outcome to future movement direction emphasised, and the implicit approach where the athletes were exposed to a sport-specific reactive situation without any instruction or feedback.
Farrow and Abernethy (2002) also compared the performance of explicit and implicit-based learning strategies on anticipatory learning within tennis. In contrasting results to the current study, the implicit group (whose task was to estimate serve velocity) significantly outperformed the explicit group at the post-training stage. Serpell et al. (2011) utilised a guided discovery approach in order to train the anticipatory ability of rugby league footballers. Although various learning strategies were not compared, using the guided discovery approach the athletes significantly improved their response times following the three-week training period. Hopwood (2011) also facilitated an increase in response time using a discovery approach, where no instruction was provided to the participants, although no significant results were found.

It should be noted that the potential success facilitated by the implementation of explicit-based learning is highly determined by: i) the nature of the explicit content provided, and ii) the similarity between the training and testing/performance environments. The nature of the explicit content provided to the participants is of vital importance to the outcome of the training. If the anticipatory cues or general postural areas highlighted to the athlete within the training setting do not serve as anticipatory cue sources within the performance/testing setting, the improvements achieved within the training setting will not transfer between settings. The anticipatory information provided to the athletes within the current study was applied from recent research that completed a biomechanical analysis on the attacking strategies (including deceptive movements) utilised by rugby athletes within a competitive 1-v-1 situation (Brault et al., 2010). The information provided to the explicit-group was therefore based on quantified data that ensured the postural anticipatory cues, highlighted in the training setting through explicit strategies, were identical to the cues available within the 1-v-1 RAT. Serpell et al. (2011) trained rugby league athletes using a guided discovery
approach, highlighting key postural areas to focus attention. The information on where to focus attention was garnered from research that identified key anticipatory cues within non-rugby league sports including soccer and tennis, which were then validated by former professional rugby league players and coaches (Serpell et al., 2011). This method may have provided the appropriate cues, as evidenced by facilitating an increase in reactive performance, however incorporating cues generated from a sport-specific biomechanical analysis, may allow for increased specificity and accuracy of the explicit instructions. The provision of anticipatory cues to learners via explicit instruction in the future will therefore benefit from a biomechanical analysis of the specific movement in order to further understand the associations between movements displayed and the resultant outcomes.

The similarity between the training setting and the performance/testing setting is also of great importance to the potential benefit of incorporating explicit-based strategies to agility performance (Cox, 2002), and was therefore a strength of this study. If the stimulus provided in the training setting is not replicated in the testing protocol, then any improvements may not transfer between the settings. This is demonstrated in Engelbrecht’s (2013) study which utilised a generic light-based stimulus within the testing protocol whilst highlighting postural anticipatory cues within the training study. The implication of this may be that studies that employ a testing protocol that is removed from the performance setting may not be appropriate to assess and compare the value of the different learning strategies. The current study utilised a representative test, in the 1-v-1 RAT, and based explicit instructions on biomechanical research on the specific strategies that attackers display within 1-v-1 situation. This therefore meant that the explicit group were provided with valid anticipatory cue instructions and could apply this information in a testing environment highly-representative of the performance setting. This may explain
why the current study achieved a decrease in response time as a result of explicit instruction while other studies have not.

The improvements seen by the explicit and implicit group within the 1-v-1 RAT following the video-based warm-up, may be explained by consulting the previously outlined theory of perceptual-cognitive adaptation. As previously stated, Williams and Ericsson (2005) posited that:

the ability to effectively pick up advanced postural cues, to scan the visual display in an appropriate manner, and to orientate attention only to the most pertinent sources of information are due to specific adaptations as a result of practice and experience of the task. (p. 298)

The results obtained within this study suggest that both an implicit and explicit-based video warm-up can be successful in facilitating an acute effect of response time in a 1-v-1 situation. Utilising a video-warm-up may have provided a mechanism in which to ‘fast-track’ the practice and experience of the task, needed to develop this specific perceptual-cognitive expertise, as suggested by Williams and Ericsson (2005).

The methods used in the current study however, did not allow the researchers to understand the perceptual-cognitive strategy being employed by the athlete and how this was altered as a result of the video-warm-up intervention. As a result, the exact mechanism that allowed for an athlete to increase their performance on the post-intervention reactive task is unclear. It is uncertain whether the video warm-up protocol served to increase the athlete’s knowledge base of attacking strategies displayed by the opponent and allow for increased ability to utilise postural cues to facilitate anticipation performance, or alternatively, whether it simply served to increase arousal levels of the athletes which
allowed them to respond faster. The defenders may have already been subconsciously aware of the attacking strategies utilised by the attackers, and the video-based warm-up acted as a mechanism to focus their attention on these information-rich areas of the display, rather than increase their declarative knowledge of the attacking player’s specific movement strategies.

5.4.1  **Contrasts between Group Perceptual Expertise Levels**

The groups were matched according to the results achieved on the performance testing batteries. This meant that physical differences between the groups were not responsible for any disparity in the results between any of the conditions. No effort was made however to quantify the level of expertise the athlete’s had within perceptually challenging tasks. It is highly possible that the video-based warm-up does not elicit the same benefit for different individuals, based on their current level of expertise. This may have had an effect on the mean level of improvement each group made as it has been shown through research that talent development is a nonlinear process (Renshaw, Davids, Shuttleworth, & Chow, 2009). In addition, it has been shown that unique differences occur in the interactions of the individual and the environment leading to varied developmental trajectories (Abbott, Button, Pepping, & Collins, 2005). It is possible that the participants with a low level of perceptual-cognitive expertise within rugby football benefited from the explicit instruction video due to a low level of stored memories on the specific task, whereas the athletes with an already developed skill in this area may have had their performance hindered due to a potential proceduralisation of the task (Green & Flowers, 1991). Research is limited in the area of acute training studies; however it is quite plausible that due to differing stages of the athlete’s perceptual-cognitive expertise development, the acute effect resulting from
5.5 Development and Effectiveness of the 1-v-1 Reactive Agility Test

As research into sport-specific agility is still primarily in its infancy, various methods in which to test and train for agility have been proposed over recent times. Testing has primarily employed video-based stimuli (Sheppard, Young, Doyle, Sheppard, & Newton, 2006), while training studies have varied in their approach and delivery. Further, the majority of studies up to this point have investigated an athlete’s ability to quickly respond to a stimulus through the use of video projected stimuli, (Farrow & Abernethy, 2003; Farrow, Young, et al., 2005; Gabbett & Abernethy, 2013; Serpell et al., 2010) or an illuminating timing light (Engelbrecht, 2011; Henry et al., 2011). This study was one of the first to test for the perceptual-cognitive component of agility in an open environment where the reactor was challenged to respond to an opponent, as is seen within the performance setting of rugby football.

Previous studies investigating agility and an athlete’s ability to react to sport-specific stimuli have primarily challenged the anticipation ability of the athlete through the use of a stimulus presented through a 2D video of an opponent (Farrow, Young, et al., 2005; Gabbett & Abernethy, 2013; Henry et al., 2011; Serpell et al., 2010). The participant is challenged to pick-up anticipatory cues provided by the athlete within the video, in order to respond efficiently. The use of two-dimensional film to display the sport-specific stimulus has however been questioned in the literature (Williams et al., 1999). As stated by Williams et al. (1999) “the loss of dimensionality may make it difficult for subjects to
accurately estimate depth, or alternatively, it may cause them to alter their habitual performance strategy” (p.108).

The use of a 2D projection as the stimulus may also exclude some information to the observer that may in fact be critical for making informed decisions. Recent research, with a focus on ecological dynamics, has highlighted the distance between the attacker and defender as a crucial constraint on the decision dynamics of the one-on-one sub-phase of sporting contests (Araujo, Davids, & Hristovski, 2006; Esteves, de Oliveira, & Araujo, 2011). This was further shown by research into basketball and junior rugby union that demonstrated that interpersonal distance and relative velocity between attackers and defenders may play a role in the interpersonal interactions between the athletes competing in a 1-v-1 situation (Headrick, 2011; Passos et al., 2008). These factors are absent when the stimuli supplying the anticipatory cues are provided through a stationary 2D video projection. The potential problems with challenging athlete’s to respond to 2D projections was also highlighted by Sheppard and Young (2006) who stated that: ‘the two-dimensional format may limit the amount and specificity of cues available to which the athlete is to react’ (p. 929). It cannot be assumed that the improvements seen within these testing protocols adequately transfer to the performance setting.

In contrast to these studies, the current study utilised a 1-v-1 situation in which the defender (responder) reacted to an actual opponent, the attacker (stimulus). Upon the starting of each trial, the athletes began to move closer to each other before an evasive manoeuvre was executed by the attacker, at which point it was the mark of a skilled defender to read and react to advanced postural cues displayed by the attacker to quickly react in the appropriate direction, thus making a successful defensive play. This
methodology allowed both the attacker and defender to perform in a setting which closely represented the performance setting. This representative design allowed for the responder’s to utilise the same anticipatory strategies as they would employ in the performance setting. Small gradations in bodily orientation that the attackers utilise in the performance setting would be available to the responder for use as an anticipatory advantage.

In addition, the attackers were challenged to execute an attacking manoeuvre in an attempt to evade the live defender. This ensured that they utilised the same attacking strategies as they would employ in the performance setting, as opposed to if they were asked to ‘act’ as they would in the performance setting for the purpose of recording their movement. The deceptive strategies executed by attackers within the performance setting can be of an implicit nature, and therefore, challenging these players to perform as they would in front of a video camera may produce different outcomes to the movements they would exhibit within the performance setting. Brault (2010) posited that the deceptive movements displayed by attackers pretending for a video camera were “arbitrary and false as they did not have to adjust to what a defender was doing” (p. 414). As a result, the methodology used in this study allowed for any observations to be highly associated with the performance setting.

The use of a 1-v-1 test, in contrast to a pre-recorded video stimulus, also posed difficulties to the research. The participants acting as attackers were not given any coaching or instruction in relation to what movements or strategies to utilise during the drill. Therefore, a wide variety of movements were displayed by the attackers, and as a result, the controllability within each trial was limited. This is the nature of rugby football sports in the performance setting, however, within the research environment, this presented
problems with the potential implications associated with the collected data. Each defender (responder) faced five attackers pre-intervention and the same five attackers post-intervention, with the average of the pre-scores statistically compared with the average of the post-scores (middle three scores in each set). However, as the attackers were not told to exhibit a specific strategy of attacking movements and skills, it is plausible that the attackers altered, whether consciously or sub-consciously, their type of attacking movement strategy from pre- to post-intervention. Therefore, a possible scenario is that the attackers did not incorporate deceptive strategies into their movement in the pre-intervention stage and then did incorporate these strategies into the post-intervention stage, making the task more difficult for the responders in the second set of trials. Alternatively, the attackers may have exhibited movements with more abundant anticipatory cues in the post-intervention period of trials, allowing the defenders to respond more quickly and efficiently and as a result, the video warm-up intervention may have been falsely believed to elicit an acute benefit to response time when in fact the second set of trials were easier to respond to, regardless of the intervention.

It must be considered however that the dynamic nature of anticipatory cues available in the performance setting does vary greatly between each situation. In addition, if the attacking players were instructed for specific strategies to utilise during the 1-v-1 RAT, a learning effect would likely have presented itself, as the responders would have been able to learn the specific strategies to scan for. Also, the coaching of the attackers to utilise specific movement tactics would have reduced the representative nature of the test, as attackers would not have been utilising their natural movements, as in the performance setting. Given the above, it is believed that the methodology used in this study provided the most realistic setting for the athletes to compete in, and as a result provided the ideal
environment for the testing and validation of the video-based warm-up as an ergogenic aid to performance.

Future research into agility would benefit from incorporating the principles of a representative design as their method of testing. The amount of controllability is an obvious drawback to testing within the performance setting; however continued efforts should be made to test athletes within an open environment, as close to the performance setting as possible. This will allow for the greatest transfer from the training to performance settings, and therefore maximal implications to be drawn from the testing results.

5.6 Effectiveness of 3D Motion Analysis for Studying Reactive Agility

This study was the first to utilise a 3D motion analysis system as a means to quantify response time within a sport-specific reactive agility testing protocol.

Using the definition of response time as ‘the sum of reaction time and movement time; i.e. the time from stimulus onset to the termination of the response, and applying to our method of application, our response time was the time between the attacking player providing the stimulus (stimulus onset), to the defender using their perceptual-cognitive skills to process the stimulus and applying this to move in the appropriate direction (termination of response). Therefore, the frame in which the outside foot (when moving to the right the outside foot was the left foot and vice versa) left the ground in the appropriate direction was identified as the point at which the participant had transferred their perceptual-cognitive skills into executing an appropriate response. Even though movement continued after this point (outside foot leaving the ground), the perceptual-cognitive
response was deemed to have ceased and their physical movement abilities had completely taken over.

Previous studies have quantified athlete’s decision time/response time by recording high-speed video of the athlete and visually assessing the participant’s movements, followed by counting the number of frames between the stimulus onset and the athlete executing his/her response (Farrow, Young, et al., 2005). Within this study, we have adapted this previously used methodology; however a twenty-camera 3D motion analysis system was employed as the information capture device. This approach was used as this methodology offered additional advantages over a standard high-speed video camera.

First, as a twenty-camera setup was used, assessment of the athlete’s movements could be assessed from all directions. This meant that as opposed to using a solitary device capturing from a single angle, many different angles could be used to assess the movements of the athlete. This allowed for greater accuracy in the assessment of movement. Secondly, as the 3D motion analysis system tracked the movement of reflective markers attached to the participant at specific sites on the foot, this allowed for more consistency in terms of the assessment of movement. Rather than attempting to visually assess the movement of an entire body segment, with the point of reference varying from trial to trial, specific landmarks were focused on that provided a framework for when a movement had been initiated and completed. The three marker positions, the toe (3rd metatarsal), the heel (calcaneus), and ankle (ankle malleolus) were used in order to allow the 3D motion analysis software (Vicon MX) to develop a model of the foot segment using these points of reference. This allowed the researchers to track the trajectory and velocity of both individual markers, and the foot segment as a whole. The
system tracked the markers in the three planes of movement within each trial and the resulting graphical output allowed the researcher to isolate the exact point in which the attacker and defender initiated their movement in a specific direction. Quantifying the measurement using this method was considered more objective than relying on the visual ability of a researcher to subjectively determine when the athlete changed direction.

The limitation of using 3D motion analysis was self-imposed by only using the foot markers within the analysis. Only using the three markers on each foot and excluding information from the remainder of the lower body (i.e. shank, thigh, and hips) may have excluded valuable information in terms of the movements being displayed by both the attacker and defender. As the primary interest was the response time of the defender’s, the time point in which the defender had applied their perceptual-cognitive skills to process the stimulus being presented by the opponent and execute an appropriate response was the primary measure. Not including information from the rest of the lower body however, on either the defender or the attacker, meant that the researcher was blind to any movement change in these areas. Utilising markers from the rest of the body, whilst time-consuming, would have allowed the researcher to more closely assess the movement strategies being utilised by the attacking players. This would have enabled the data to be grouped by the type of attacking strategy being implemented by the attacker, rather than all together, which may have impacted on the mean result. Correlations could then have been drawn between the strategies being employed by the attacker (e.g. type of step, deceptive strategies, disguise strategies) and the resultant effect on the defender’s response time. This is an obvious area for future research, that being to determine the effects that different attacking movement strategies have on a defender’s response time.
Chapter 6 - Conclusion, Implications & Suggestions for Future Research

6.1 Conclusion

The key findings of this study, in line with the research aims outlined in chapter 1, were:

1. The 3D motion analysis as used in this study had effectively quantified reactive performance within a sport-specific reactive agility test and demonstrated a moderate level of reliability (ICC level of 0.638).

2. A significant acute effect on reactive performance was found in response to the use of a video-based warm-up protocol. This video warm-up protocol elicited significant relative performance improvements of 15.7 and 19.1% for the implicit- and explicit-video groups, respectively, in comparison to the control group’s non-significant 4.6% improvement. This therefore indicated that the video-based warm up protocol was successful in eliciting an acute effect on reactive performance. No significant interaction effect was produced and therefore the research hypothesis could not be accepted with confidence.

3. There was no significant difference between the use of an implicit-based and an explicit-based strategy in providing an acute effect to sport-specific reactive performance.

6.2 Study Implications

The current study demonstrated that an acute improvement in sport-specific response time can be facilitated through the use of a video-based warm-up utilising both implicit and
explicit learning strategies. The implication of this finding may be that utilising a video-based warm-up prior to performance may increase subsequent sport-specific reactive ability for athletes who compete in open-type sports where they are required to respond to the movements of opposition athletes.

This finding may add a new dimension to pre-game athlete preparation. Coaches may prescribe this training to athletes prior to performance in order to facilitate an increase in reactive ability in the performance setting. As this intervention does not require movement, athletes may use this training protocol in the transit time to the game venue or in the change rooms prior to performance. Athletes within this study completed the testing immediately following the video intervention. Therefore, a possible increase in agility as a result of the video intervention may be reduced with an increased time between video intervention and performance, thus affecting its applicability to game day preparation.

### 6.3 Suggestions for Future Research

Specifically, this study extended upon the previous research by:

- developing an ecologically-valid novel agility test specific to rugby football that utilised a game specific 1-v-1 situation;
- utilising a 3D motion analysis system to quantify the athlete’s perceptual-cognitive ability;
- assessing the efficacy of incorporating a video-based warm-up to deliver an acute effect to reactive performance;
- comparing explicit- and implicit-based learning strategies for their ability to promote an acute benefit to reactive performance; and
• applying recent biomechanical research into the attacking strategies employed by rugby football players to train for rugby football-specific anticipation ability using explicit-based videos.

Future research in the area of testing and training agility, specifically in the area of increasing an athlete’s perceptual-cognitive ability, may extend the literature further by:

• Developing sport-specific reactive agility testing protocols that allow the athlete’s to perform within a setting highly-representative of the performance environment. Efforts should be made to utilise an ecologically-valid testing protocol while also increasing the controllability of the testing.

• Performing in-depth biomechanical analyses of high-level athlete’s from a variety of sports competing in their specific performance setting, to allow for further understanding of the key anticipatory information areas and their associations with future movements. This will allow for the coaching of effective anticipatory strategies in a variety of sports.

• Studying the benefit of implicit-based and explicit-based learning strategies to anticipation training, based on the athlete’s current level of anticipation expertise. It may be that the efficacy of the different learning strategies is highly reliant upon the athlete’s current level of expertise. As opposed to a ‘one learning strategy fits all’ approach, the different types of learning should be compared for their benefit to different skill levels.

• This study showed that an acute improvement in agility is possible using video-training. Future studies may implement an agility training programme over a
longer time period with testing throughout the training period. This will allow for the understanding of how anticipation skill progresses over the training period.
References


Baker, D., & Newton, R. (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among


Appendices

Appendix A - Explicit Video Instruction Transcript

Clip 1: The attacking player uses the deceptive tactic of turning the upper body in the opposite direction in which they are going to step. The hips remain facing forward which is necessary to change direction. The left leg (from the defenders perspective) is planted wide outside the body’s centre of gravity indicating a strong step to the right.

Clip 2: The attacking player once again rotates the upper body and head in the opposite direction in an attempt to fool the defender. The hips however, which are an accurate predictor of future movement direction remain facing forward, thereby facilitating a change of direction to the right. This shows that an effective strategy of defensive anticipation is to focus on the hips rather than the upper body.

Clip 3: The player while maintaining neutral hips (that is they are not turned to the left or right), moves the outside foot (shown in the yellow circle) is to the left thus allowing an explosive change of direction to the right.

Clip 4: The attacker uses a common deceptive movement of turning the upper body in the opposite direction in which they are going to move in an attempt to fool the defender. Notice that the hips remain facing forward which is necessary for the attacker to change direction to the left.

Clip 5: The attacker attempts to deceive the defender by turning the upper body in the opposite direction in which they are going to step. The position of the hips is an accurate indicator of the attacker’s intentions as is shown here by the attacker turning the hips to the left.

Clip 6: The attacker turns the upper body to the left to deceive the defender. The defender should focus their attention on the hips which remain neutral thus allowing for the change of direction to the right.

Clip 7: The attacker uses the deceptive movement of turning both the upper body and head in the opposite direction in which they will step. The outer foot movement to the right allows the attacker to explosive change direction to the left.

Clip 8: As the attacker approaches the defender, they drop their body weight and the outer foot (highlighted by the red arrow) is extended to the left to allow for a powerful change of direction to the right.

Clip 9: Earlier in the action sequence, notice the attacker moves the outer leg shown by the red line) outside the path of their normal running pattern. This is an early clue that the attacker will change direction to the left.
Clip 10: After a slight jump, notice the landing position of the attacker. The outside leg (shown by the red arrow) is placed further from the centre of mass (highlighted by the yellow perpendicular line) indicating a change of direction to the left.

Clip 11: The attacker uses the deceptive movements of turning the upper body and head in the opposite direction to which they will step. Notice the hips remain neutral (that is, facing forward) thus allowing the attacker to change direction.

Clip 12: Again notice the placement of the outside foot (shown by the red arrow) in relation to the centre of mass (shown perpendicular yellow line). This is a clue that the defender will change direction to the right.

Clip 13: The attacker does not use any deceptive movements to fool the defender. A valuable clue in anticipating the stepping direction of the attacker is shown by the outside foot placement.

Clip 14: The attacker turns the upper body and head to the left. This can often be used as a deceptive movement however. The hips (which are an accurate indicator of stepping direction) are also turned to the left, thus indicating the attacker will move to the left.

Clip 15: The upper body and head are turned to the left. However, the hips which often signal the attacker’s true intentions are turned slightly to the right, thus showing the defender will step in this direction.

Clip 16: Again, the attacker attempts to fool the defender by exaggerating their upper body movements to the left. Again notice the hips remain neutral and the outside foot placement indicates an explosive movement to the right.

Clip 17: The attacker plants the right leg (shown by the red line) outside the path of their normal running pattern, indicating a change of direction to the left.

Clip 18: The attacker plants the left leg (shown by the red arrow) a marked distance from the centre of gravity, indicating a sharp stepping movement to the right.

Clip 19: The attacker’s hips remain neutral whilst the outside foot is planted to the right indicating a stepping movement to the left.

Clip 20: The attacking athlete plants the right leg and drops his body weight to facilitate a powerful step to the left.

Clip 21: The athlete uses a deceptive movement of turning the upper body and head in the opposite direction to that in which they will step. The hips do not display the same deceptive turning movement, thus provide an accurate indicator of stepping direction.
Clip 22: This athlete shows a greatly exaggerated turning of the upper body and head. To allow for a change of direction, the athlete must rotate the hips back to a neutral position (that is facing forward) prior to executing the step and thus the hips provide an early clue into stepping direction.
Appendix B – Information Sheet for Parents

Information Sheet for Parent/Guardian
This information is yours to keep

Does the use of an implicit &/or explicit video-based warm-up protocol improve ‘1-on-1’
defensive performance in rugby league?

Brief Background to project: Rugby League is a full-contact sport requiring players to excel
in many facets of fitness including strength, power, endurance and speed in addition to game
skills and tactical awareness. One of the primary indicators of an elite rugby league player is
agility. Often agility is trained through the use of change-of-direction speed drills; however
previous research has indicated that reactive ability to sport-specific stimuli is the best
discriminator of agility prowess. Therefore, it has become apparent that improving reactive
ability is the next step in improving a player’s movement skills. The purpose of this study is to
establish if watching videos of opposition players executing stepping and cutting manoeuvres,
will enhance a player’s ability to anticipate movement direction by becoming more efficient at
utilising cues in the opponent’s bodily orientation. This could result in the player being able to
move faster and more effectively. A ‘1-v-1’ game-like drill will be utilised along with high-
speed cameras assessing movement times. Videos will be utilised as part of the warm-up
protocol in order to assess their effectiveness.

What this project involves: The following describes the nature of your involvement
in these tests, should you agree to participate:

- Participant’s age, height, weight, and skinfold measurements will be recorded.

- You will be asked to attend three (3) testing sessions. Within the first testing session,
  players will undergo testing for twenty metre linear speed and change-of-direction
  (COD) speed. The L-Run will be used as the testing battery for COD speed.
  Participants will complete three 20m sprints and three L-run tests.

- The second testing session will involve completing a ‘1-v-1’ drill over 10 metres.
  Each drill starts with an attacker and a defender situated at opposite end of a playing
  area of 10m x 6m. At the commencement of the drill, the attacking player, who will be
  holding a rugby league ball, moves forward and tries to evade the defender and reach
  one of two “gates” identified by marker cones. The defender, moves forward at the
  start of the drill with the aim of making a two-handed tag on the attacker. The drill
concludes when either the attacker reaches the one of the end-gates or the defender makes a two handed tag, which is the measure of a successful tackle. Four cameras will be set-up at the corner of the playing area which will be used to quantify movement and reaction times. Each participant will complete five (5) drills as the defender. All testing sessions will take place in the P Block indoor basketball court. All players will complete a standardised warm-up prior to testing.

The third testing session will be the same as the second testing session. However prior to the 1-v-1 tests, players will be sorted into different experimental groups. Each group will participate in a different warm-up protocol. Groups 1 and 2 will view video clips of opposition players running at them and executing a stepping manoeuvre. Group 3 will do opposed field drills including simple elimination drills. Group 4 will serve as the control and will perform neither a video nor a field-based warm-up.

Possible discomforts and risks: As with all sport specific studies, a small risk of injury exists. The 1-v-1 playing area is only over a length of 10m and therefore participants will not be able to reach maximal sprinting speeds. This therefore reduces the likelihood of injury. Any contact made between participants within the drill will be of a two-handed touch nature and therefore no tackle collision will occur. As the drill involves stepping manoeuvres, a small chance of ankle injury is present. To counter this chance, participants are required to wear non-slip shoes. Also, the wooden basketball court surface will be swept clean prior to testing. Ice and first aid supplies will be present in the unlikely event of any injury and accidents.

Your role: Should you agree to participate, you will be asked to attend one information session and three (3) testing sessions. During the information session the protocols will be explained. One testing session will be used to assess linear speed and change-of-direction speed in addition to body assessments (height, weight and skinfolds). Two testing sessions will include the completion of the 1-v-1 agility test with the final session including either a video-based or field based warm-up.

You should stay well hydrated on the day of testing. Participants will also be requested to refrain from completing any heavy training in the 48 hours prior to testing. In particular lower body training including sprinting and lower body resistance training should not be performed for 48 hours prior to testing as this may have a negative effect on performance and possibly distort the results of the study.

You are free to withdraw from this research project at any time. There will be no repercussions as a result of your withdraw. If you do decide to withdraw from the study, it would be appreciated if you could advise the principal researcher.

Outcomes: It is hoped that the results of the study will provide valuable information regarding the effects of including video training as part of a rugby league warm-up protocol. If a significant result is found with the study then this could have great benefits for rugby league players.

Should you have any questions about the above please do not hesitate to contact:

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Principal Researcher
Tel: (02) 66203655
ryan.holding@scu.edu.au

Professor Shi Zhou
Principal Supervisor
Tel: (02) 66203991
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Dr. Rudi Meir
Co-supervisor
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rudi.meir@scu.edu.au
Appendix C – Information Sheet for Participants

Information Sheet for Participant
This information is yours to keep

Does the use of an implicit &/or explicit video-based warm-up protocol improve ‘1-on-1’ defensive performance in rugby football sports?

Brief Background to project: Rugby football (rugby union / rugby league) is a full-contact sport requiring players to excel in many facets of fitness including strength, power, endurance and speed in addition to game skills and tactical awareness. One of the primary indicators of an elite rugby football player is agility. Often agility is trained through the use of change-of-direction speed drills; however previous research has indicated that reactive ability to sport-specific stimuli is the best discriminator of agility prowess. Therefore, it has become apparent that improving reactive ability is the next step in improving a player’s movement skills. The purpose of this study is to establish if watching videos of opposition players executing stepping and cutting manoeuvres, will enhance a player’s ability to anticipate movement direction by becoming more efficient at utilising cues in the opponent’s bodily orientation. This could result in the player being able to move faster and more effectively. A ‘1-v-1’ game-like drill will be utilised along with 3D motion analysis cameras assessing movement times. Videos will be utilised as part of the warm-up protocol in order to assess their effectiveness.

What this project involves: The following describes the nature of your involvement in these tests, should you agree to participate:

- Participant’s age, height, weight, and anthropometric measurements will be recorded.
- You will be asked to attend three (3) testing sessions. Within the first testing session, players will perform testing for twenty metre linear speed and change-of-direction (COD) speed. The L-Run will be used as the testing battery for COD speed. Participants will complete three 20m sprints and three L-run tests.
- The second testing session will involve completing a non-contact ‘1-v-1’ drill over 10 metres. Participants will have four, markers placed on the shoe to allow for motion analysis. Each drill starts with an attacker and a defender situated at opposite end of a playing area of 10m x 6m. At the commencement of the drill, the attacking player, who will be holding a rugby league ball, moves forward and executes a side-step and moves through one of two “gates” identified by marker cones. The defender, moves forward at the start of the drill with the aim of reaching the gate (in the same direction as the attacker) as quickly as possible. The drill concludes when both the attacker and
defender pass through the gates. 10 motion analysis cameras will be set-up around the playing area which will be used to quantify movement and reaction times. Each participant will complete five (5) drills as the defender. All testing sessions will take place in the P Block indoor basketball court. All players will complete a standardised warm-up prior to testing. Following the completion of the 5 trials, players will be sorted into 3 different experimental groups. Each group will participate in a different video warm-up protocol. These groups will view video clips of opposition players running at them and executing a stepping manoeuvre. Following the video warm-up, players will return and complete an additional 5 trials of the 1-v-1 agility test.

- Session three will be a repeat of session two. Both sessions two and three will last approximately one hour.

- **Possible discomforts and risks:** As with all sport specific studies, a small risk of injury exists. The 1-v-1 playing area is only over a length of 10m and therefore participants will not be able to reach maximal sprinting speeds. This therefore reduces the likelihood of injury. As the drill involves stepping manoeuvres, a small chance of ankle injury is present. To lower this risk, participants are required to wear non-slip shoes. Also, the wooden basketball court surface will be swept clean prior to testing. Ice and first aid supplies will be present in the unlikely event of any injury and accidents.

**Your role:** Should you agree to participate, you will be asked to attend three (3) testing sessions. One testing session will be used to assess linear speed and change-of-direction speed in addition to body assessments (height, weight and anthropometric data). Two testing sessions will include the completion of the 1-v-1 agility test with a video-based warm-up. You should stay well hydrated on the day of testing. Participants will also be requested to refrain from completing any heavy training in the 48 hours prior to testing. In particular lower body training including sprinting and lower body resistance training should not be performed for 48 hours prior to testing as this may have a negative effect on performance and possibly distort the results of the study.

You are free to withdraw from this research project at any time. There will be no repercussions as a result of your withdraw. If you do decide to withdraw from the study, it would be appreciated if you could advise the principal researcher.

**Outcomes:** It is hoped that the results of the study will provide valuable information regarding the effects of including video training as part of a rugby football warm-up protocol. If a significant result is found with the study then this could have great benefits for rugby football players.

Should you have any questions about the above please do not hesitate to contact:

Ryan Holding  
Principal Researcher  
Tel: (02) 66203655  
ryan.holding@scu.edu.au

Professor Shi Zhou  
Principal Supervisor  
Tel: (02) 66203991  
shi.zhou@scu.edu.au

Dr. Rudi Meir  
Co-supervisor  
Tel: (02)66203911  
rudi.meir@scu.edu.au
Appendix D – Informed Consent Sheet

Informed Consent Sheet

This consent form is based on Guidelines from the National Statement on Ethical Conduct Involving Human Participants as issued by the NHMRC.

Name of Project: Does the use of an implicit &/or explicit video-based warm-up protocol improve ‘1-on-1’ defensive performance in rugby football sports?

Researchers: All member of the research team, Ryan Holding, Shi Zhou and Rudi Meir are located at:
The School of Health and Human Sciences,
Southern Cross University, Lismore 2480

NOTE: This consent form will remain with the Southern Cross University researcher for their records

Tick the box that applies, sign and date and give to the researcher:

I agree to participate in the above research project. I have read and understand the details contained in the Information Sheet. I have had the opportunity to ask questions about the study and I am satisfied with the answers received. Yes □ No □

I have been provided with information at my level of comprehension about the purpose, methods, demands, risks, inconveniences, discomforts, and possible outcomes of this research (including any likelihood and form of publication of results). Yes □ No □

I understand that I am free to discontinue participation at any time and without any negative consequences to me personally. I have been informed that prior to data analysis, any data that has been gathered before withdrawal of my consent will be destroyed. Yes □ No □

I understand that any personal information which may identify me will be de-identified at the time of analysis of any data. Therefore, I, or information I have provided, cannot be linked to my person. Yes □ No □

I agree to complete questionnaires asking about my general health and training status. Yes □ No □

I understand that if I am a student, colleague or associate of the research team, my decision to participate or not to participate will have no influence on my interaction/relationship with the researcher at an academic or professional level. Yes □ No □

I understand that all information gathered in this research is confidential. It is kept securely Yes □ No □
and confidentially for a minimum of 7 years at the university. After this time it will be destroyed.

I am aware that I can contact the Principal Researcher or Supervisors at any time with further enquiries, if necessary. Yes ☐ No ☐

I have read the information above and agree to participate in this study. I am over the age of 18 years.

Name of Participant: .................................................................................................................................

Signature of Participant: ........................................ Date: ..............................................................................

☐ Please tick this box and provide your email address below if you wish to receive a summary of the results:

Email: .........................................................................................................................................................
Appendix E – Parent Permission Form

Parent/Guardian Consent Form

Sign and Return to the Research Team

Name of Project: Does the use of an implicit &/or explicit video-based warm-up protocol improve ‘1-on-1’ defensive performance in rugby league?

I ………………………………………………………………………………………………….. (Parent/Guardian) agree
to allow ………………………………………………………………….. (Name of child) to participate in
this Southern Cross University research project as per the protocol described on the
information sheet.

In signing this Informed Consent Form I agree to allow my child to take part in the
research project while also under the supervision of the research team.

I understand that my child wishes to participate and that my child is aware that
participation is completely voluntary and that they may withdraw from the activities at any
time without penalty.

Signature of Parent/Guardian: ……………………………………………………………..

Date: ………………………………………………………..
Appendix F – ESSA Health Screen Questionnaire

### ADULT PRE-EXERCISE SCREENING TOOL

This screening tool does not provide advice on a particular matter, nor does it substitute for advice from an appropriately qualified medical professional. No warranty of safety should result from its use. The screening system is no way guarantees against injury or death. No responsibility or liability whatsoever can be accepted by Exercise and Sports Science Australia, Fitness Australia or Sports Medicine Australia for any loss, damage or injury that may arise from any person acting on any statement or information contained in this tool.

#### Name:

#### Date of Birth: Male [ ] Female [ ] Date:

#### STAGE 1 (COMPULSORY)

**Aim:** To identify those individuals with a known disease, or signs or symptoms of disease, who may be at a higher risk of an adverse event during physical activity/exercise. This stage is self-administered and self-evaluated.

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<td>1. Has your doctor ever told you that you have a heart condition or have you ever suffered a stroke?</td>
<td>Yes</td>
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<td>2. Do you ever experience unexplained pains in your chest at rest or during physical activity/exercise?</td>
<td>Yes</td>
<td>No</td>
</tr>
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<td>3. Do you ever feel faint or have spells of dizziness during physical activity/exercise that causes you to lose balance?</td>
<td>Yes</td>
<td>No</td>
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<td>4. Have you had an asthma attack requiring immediate medical attention at any time over the last 12 months?</td>
<td>Yes</td>
<td>No</td>
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<td>5. If you have diabetes (Type I or Type II) have you had trouble controlling your blood glucose in the last 3 months?</td>
<td>Yes</td>
<td>No</td>
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<td>6. Do you have any diagnosed muscle, bone or joint problems that you have been told could be made worse by participating in physical activity/exercise?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7. Do you have any other medical condition(s) that may make it dangerous for you to participate in physical activity/exercise?</td>
<td>Yes</td>
<td>No</td>
</tr>
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**IF YOU ANSWERED 'YES' to any of the 7 questions, please seek guidance from your GP or appropriate allied health professional prior to undertaking physical activity/exercise.**

**IF YOU ANSWERED 'NO' to all of the 7 questions, and you have no other concerns about your health, you may proceed to undertake light-moderate intensity physical activity/exercise.**

I believe that to the best of my knowledge, all of the information I have supplied within this tool is correct.

Signature: __________________________ Date: __________________________

[ESSA logo] [Fitness Australia logo] [Sports Medicine Australia logo]
Appendix G – VICON Setup Photos
### Subgroup 1

#### Session 1

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*Notes:*
- "C" indicates a condition.
- "x" indicates data not available or not applicable.
### Subgroup 1

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Subgroup 2

Session 2

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Subgroup 3

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Subgroup 5

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165.
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