Interaction between situational probability information for cricket batsmen when anticipating a bowler's intentions

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DECLARATION:

In accordance with Rule G4.6.3, I hereby declare that the above-mentioned treatise is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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Abstract

The ability to anticipate the bowler's intention is vital in skilled cricket batting. Two perceptual-cognitive skills used for anticipation include use of kinematic information and the use of situational probability information. This study aims to investigate the interaction between two sources of situational probability (action preferences of bowlers and opposition field placement) used by skilled cricket batsmen to anticipate the bowler's intention in an in-situ setting. Fifteen skilled cricket batsmen were required to predict the delivery outcome (landing position) of 72 deliveries bowled by a bowling machine before attempting to strike each delivery. These deliveries were divided into four conditions of situational probability: no sources (control trials); field placement alone; action preference alone; and both field placement and action preferences. Data were collected according to batsmen's prediction accuracy, response accuracy, and initial movement time. In the presence of situational probability information, batsmen were able to predict delivery outcome significantly better than chance level (25%) and control trials. Results revealed significant differences between sources of situational probability in terms of batsmen's prediction accuracy but not response accuracy or initial movement time. In cricket batting, it appears that some sources of situational probability information are more valuable than others.

Keywords: Anticipation; Situational probability; Cricket

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Chapter 1: Problem Identification

1.1. Introduction

Cricket batsmen are required to hit a leather ball with a wooden bat in such a way as to prevent the ball from hitting the stumps or being caught by one of the 11 opposition players. In the sport of cricket, the time taken for the ball to travel the distance between the bowler and the batsman can be less than 0.5 seconds (s) (Müller, Abernethy & Farrow, 2006). Even for relatively slow bowling velocities of approximately 110km/hr, the time required for essential perception and movement of the batsman exceeds the flight time of the ball (Müller & Abernethy, 2012). For each isolated passage of play where a ball is bowled, the batsman must make a decision concerning the type of ball that is going to be bowled, as well as the movement in response (Cotterill, 2014). Responding under such time constraints creates the need to prepare some or all components of the skill prior to ball flight (Müller & Abernethy, 2012). For this reason, the ability for a skilled performer to anticipate an opposition's intentions is crucial as it enables the performer to overcome such time constraints and provides a way for the performer to overcome possible deception of an opponent (Müller, Abernethy, Reece, Rose, Eid, McBean, Hart & Abreu, 2009).

The ability to make predictions of action-outcomes in sports can stem from two extensive categories of perceptual-cognitive skills: kinematics of the opponent; as well as non-kinematic sources such as situational probability information (Loffing & Cañal-Bruland, 2017). Kinematic information that can be used for anticipation includes the usage of postural cues (the ability to pick-up advanced cues from the postural orientation of opponents) (Roca & Williams, 2016). For example, skilled cricket batsmen have been found to make use of the wrist angle of the opponent's bowling arm to help prepare an early response. However, in striking sports such as cricket and table tennis, it has been reported that acquisition of information from ball bounce and/or ball flight may be impossible due to the time constraints resulting from high ball velocities. Therefore, under these severe time limitations, the lone source of information available used to respond may be probability information (Müller & Abernethy, 2006).

While speaking about the 2007 Rugby World Cup Final, John Smit, the South African captain at the time had the following comments regarding England Fullback, Jason Robinson: "There was a moment in the first half where he got some broken ball possession, and I was the guy in the middle of the field having to defend him. I thought, 'Okay I'm going for the left shoulder.' He did thankfully step onto my left shoulder. He was one of the guys that we had done a huge amount of analysis on. The only reason I chose to go left is because I couldn't leave a guy like Jason to the last minute to make a decision. I just wasn't mobile enough to be able to adapt. But we figured out that his preference was more than 70% to step off the left foot, so it was a reasonably calculated guess." (World Rugby, 2018).

In this situation, John Smit clearly relied on some sort of non-kinematic, probabilistic information. From this example, it can be suggested that the use of situational probability information is likely to be critical to skilled performance in sports as it aids the performer in making vital decisions or judgements of opponents' movement. In a cricket example, a batsman may use this information to decide whether to make forward or backward foot movements in cricket in order to optimally position the body for making bat-ball contact (Müller & Abernethy, 2012). It has been found that highly skilled performers are able to rely exclusively on situational probability information (even without kinematic sources) to anticipate at better than chance or guessing levels (Murphy, Jackson, Cooke, Roca, Benguini and Williams, 2016). In addition, the importance of contextual information is likely to increase as the temporal demands of the task increase (Cañal-Bruland & Mann, 2015).

At least two probabilistic sources can be of use to the batsmen in the sport of cricket. This includes the use of opposition field placements in cricket, which may suggest the intention of the bowler before the ball is actually delivered (Müller & Abernethy, 2012);

as well as potential action preferences of the bowler. The use of tactical situational probability information allows performers to construct a unique model of their opponent. For example, whether or not an opponent has certain action preferences, such as having a preference to bowl one particular type of delivery in a particular situation. This can be based upon information from previous exposure to the opponent or from the current playing situation (McRobert, Ward, Eccles and Williams, 2011).

While the importance of kinematic cues and situational probability information has been established, it is possible that successful anticipation is dependent on the integration of both of these perceptual-cognitive skills in cricket batting. Ultimately, probability and/or kinematic information is sufficient to give the skilled performer an idea of the appropriate “ball-park” location to which to move to produce a successful movement outcome. Once this global information is used, much later occurring and more precise information (such as ball flight) is used to fine-tune the motor response. Hence, the prediction of flight direction is refined by a progressive alternation from situational probability information to more localized kinematic information (Müller & Abernethy, 2012).

Although sources of situational probability information have been studied independently of one another, there is limited South African literature pertaining to the topic, as well as limited international literature surrounding the interaction of these sources in a sporting context. It has become common for sporting teams to make use of performance analysts in order to inform players and coaches about the patterns of behaviour of their opponents. Therefore, two recent opinion papers (Cañal-Bruland & Mann, 2015; Roca & Williams, 2016) have called for investigations to develop a better understanding of how different sources of situational probability interact and influence decision making or anticipatory behaviour. This justifies the need for further research in this field.

1.2. **Research Aim and Objectives**

1.2.1. Research Aim

The aim of this study is to investigate the interaction between two sources of situational probability (action preferences of bowlers and opposition field placement) used by skilled cricket batsmen to anticipate the bowler's intention in an in-situ setting.

1.2.2. Research Objectives

In order to achieve the aim of this study successfully, the following objectives were addressed:

- To describe and compare the prediction accuracy of cricket batsmen when anticipating the delivery outcome in an in-situ setting, in terms of:
  - Conditions of situational probability information provided
  - Categories of congruency
  - Combinations of condition and congruency

- To describe the level of certainty associated with the prediction accuracy of cricket batsmen when anticipating the delivery outcome in an in situ-setting.

- To describe the verbal report associated with the prediction accuracy of cricket batsmen when anticipating the delivery outcome in an in-situ setting.

- To describe and compare the response accuracy of cricket batsmen when responding to a delivery in an in-situ setting, in terms of:
  - Conditions of situational probability information provided
  - Categories of congruency
  - Combinations of condition and congruency

- To describe and compare the initial movement time of cricket batsmen when responding to a delivery in an in-situ setting, in terms of:
  - Conditions of situational probability information provided
  - Categories of congruency
  - Combinations of condition and congruency

1.3. Statistical Hypotheses

Statistical hypotheses were formulated for this study in terms of prediction accuracy, response accuracy and initial movement times.

1.3.1. Prediction Accuracy

The following statistical hypothesis was formulated for prediction accuracy:

PA H_0: $PA\mu_1 = PA\mu_2 = PA\mu_3 = PA\mu_4$

Where:

$PA\mu_1$ = Prediction accuracy for trials containing no sources of situational probability;

$PA\mu_2$ = Prediction accuracy for trials containing action preferences alone;

$PA\mu_3$ = Prediction accuracy for trials containing field placement alone;

$PA\mu_4$ = Prediction accuracy for trials containing both action preferences and field placement

PA H_1: $PA\mu_1 \neq PA\mu_2$

PA H_2: $PA\mu_1 \neq PA\mu_3$

PA H_3: $PA\mu_1 \neq PA\mu_4$

PA H_4: $PA\mu_2 \neq PA\mu_3$

PA H_5: $PA\mu_2 \neq PA\mu_4$

PA H_6: $PA\mu_3 \neq PA\mu_4$

1.3.2. Response Accuracy

The following statistical hypothesis was formulated for response accuracy:

RA H_0: $RA\mu_1 = RA\mu_2 = RA\mu_3 = RA\mu_4$

Where:

$RA\mu_1$ = Response accuracy for trials containing no sources of situational probability;

$RA\mu_2$ = Response accuracy for trials containing action preferences alone;

$RA\mu_3$ = Response accuracy for trials containing field placement alone;

$RA\mu_4$= Response accuracy for trials containing both action preferences and field placement

RA H_1: $RA\mu_1 \neq RA\mu_2$

RA H_2: $RA\mu_1 \neq RA\mu_3$

RA H_3: $RA\mu_1 \neq RA\mu_4$

RA H_4: $RA\mu_2 \neq RA\mu_3$

RA H_5: $RA\mu_2 \neq RA\mu_4$

RA H_6: $RA\mu_3 \neq RA\mu_4$

1.3.3. Initial Movement Time

The following statistical hypothesis was formulated for initial movement times:

IMT H_0: $IMT\mu_1 = IMT\mu_2 = IMT\mu_3 = IMT\mu_4$

Where:

$IMT\mu_1$ = Initial movement time for trials containing no sources of situational probability;

$IMT\mu_2$ = Initial movement time for trials containing action preferences alone;

$IMT\mu_3$ = Initial movement time for trials containing field placement alone;

$IMT\mu_4$ = Initial movement time for trials containing both action preferences and field placement

IMT H_1: $IMT\mu_1 \neq IMT\mu_2$

IMT H_2: $IMT\mu_1 \neq IMT\mu_3$

IMT H_3: $IMT\mu_1 \neq IMT\mu_4$

IMT H_4: $IMT\mu_2 \neq IMT\mu_3$

IMT H_5: $IMT\mu_2 \neq IMT\mu_4$

IMT H_6: $IMT\mu_3 \neq IMT\mu_4$

1.4. Concept Explanation

The following concepts are clarified in order to facilitate the understanding of this research study:

Delivery- The act of bowling the ball in cricket (Swanton & Plumtre, 1981).

Full-Length- A full-length delivery refers to a ball that bounces close to the standing position of the batsman on the cricket pitch (Müller *et al.*, 2009).

In-situ setting- An experimental test that is conducted in settings such as a performance laboratory or the actual sport skill setting such as a volleyball court; (b) where a performer competes against an opponent authentic to the sport skill setting; (c) where the object to be intercepted is delivered by the opponent to the performer at a similar speed (safety permitting) with those experienced in the sport skill setting; and (d) where visual-perceptual information occurring both prior to and during object flight is available to the performer to guide physical movements to intercept an object (Müller, Brenton & Rosalie, 2015).

Leg-Side- The side to the left of the right-handed batsman as he takes his stance sideways onto the bowler (Sportsdefinitions.com,2018).

Off-Side- The side to the right of the right-handed batsman as he takes his stance sideways onto the bowler (Sportsdefinitions.com,2018).

Situational Probability- The concept of situational probability involves recognition of a given situation and mobilisation of knowledge used to efficiently focus a performer's attention to relevant information (Milazzo, Farrow, Ruffault and Fournier, 2016).

Short-Length- A short length delivery refers to a delivery that bounces closer to the bowler and further away from the standing position of the batsman (Müller *et al.*, 2009).

Initial Movement Time- Initial movement time in the current study was considered to be the difference in time between the participant's first preparatory foot movements and the ball exiting the bowling machine. This is similar to the methods used by Milazzo *et al*. (2016) when investigating decision time.

1.5. Scope of the Study

This study was classified as a one group post-test-only design and employed a quantitative approach. A non-probability, purposive and convenient sampling technique was used. The participants who took part in this study were cricket batsmen over the age of eighteen. Participants were required to belong to one of the top five senior cricket clubs in Nelson Mandela Bay, and to be one of the top six batsmen of their team (determined by their team's batting order).

The participants who met the inclusion criteria were selected to participate in the study and their data were used for analysis purposes. In an in-situ setting, participants were required to predict, using a verbal response, the outcome of 72 deliveries in terms of the line and length of the landing position. Participants were provided with situational probability information in order to inform their prediction. The participants were also required to attempt to make successful bat-ball contact for each delivery. The data was used to compare which source of situational probability was valued the most by cricket batsmen.

1.6. Significance of the Study

In high-performance sports such as cricket, there are fine margins between winning and losing. The use of successful anticipation may provide an important advantage for cricket batsmen. The information collected from this study can potentially be used to educate and inform cricket players and coaches about the importance of using sources of situational probability information; as well as which of the sources provided in this study are the most important to batsmen when anticipating a bowler's intentions.

Additionally, this study attempts to address two recent opinion papers (Cañal-Bruland and Mann, 2015; Rocca and Williams, 2016) which have called for investigations to develop a better understanding of how different sources of situational probability interact and influence decision making or anticipatory behaviour.

1.7. Advanced Organizer

This research study will consist of five chapters:

- Chapter 1: Problem identification- This chapter addresses the reason for this study as well as the aims, objectives and hypotheses.
- Chapter 2: Literature review- This chapter will provide a review of the existing literature surrounding the relevant topic.
- Chapter 3: Research design- This chapter will describe the methods used to collect the data for the study.
- Chapter 4: Results- This chapter will provide the results collected during the data collection procedures.

- Chapter 5: Discussion- This chapter will provide a discussion and explanation of the results collected during the study as well as provide suggestions regarding the practical implications of the study.

Chapter 2: Literature Review

2.1. Introduction

The focus of this study is to investigate the interaction between two sources of situational probability (action preferences of bowlers and opposition field placement) used by skilled cricket batsmen to anticipate the bowler's intention. In order to place this study into perspective and to provide background information that will facilitate the discussion of the findings, this chapter provides a review of related literature. This chapter begins by providing an overview of the spatiotemporal demands placed on cricket batsmen which enforce the need for the anticipation of the bowler's intentions for successful performance. Two perceptual-cognitive skills (namely the use of kinematic cues, and the use of different types of situational probability information) will be highlighted using empirical research conducted in the field of anticipation. The final section of this chapter will highlight the integration of these two perceptual-cognitive skills in relation to anticipation in sport.

2.2. Spatiotemporal Demands of Dynamic Interceptive Actions

In fast ball sports such as cricket, tennis, baseball, football and hockey, the time constraints placed upon perception and action are severe. Movement and reaction time constraints must be dealt with, and processing of decisions needs to be continuously made with high precision within milliseconds. All of this must occur within an environment where the opponents attempt to maximize spatial and temporal uncertainty through the use of deception and confusion (Müller *et al.*, 2006). The successful performance in these situations depends on the performer's ability to read others' intentions, especially in situations where the short distances between opponents and/or high ball speeds impose considerable spatiotemporal constraints on performers (Loffing, Stern &

Hagemann, 2015). It has been proposed that the perceptual component of striking a moving object lies on the judgements of ‘where’ and ‘when’. A performer needs to be aware of the position of the ball as well as the instant of time in which it will be in that particular position (Gray, 2002).

Batting in cricket is a typical example of a dynamic interceptive action in sport and provides an ideal scenario for studying the interactions between perception and action (Stretch, Bartlett & Davids, 2000). In the sport of cricket, there exists a balanced contest between the perceptual-cognitive and motor skills of the batsman; and the skill and strength of the bowler (including fast, swing, spin and seam bowlers) (Land & McLeod, 2000; Stretch *et al.*, 2000). The limits of the visual-motor system are revealed when the fastest bowlers challenge the abilities of the best batsmen. At the most elite level of competition, the ball can be bowled at the batsman at velocities exceeding 140km/hr. At these high speeds, the ball takes less than 500 milliseconds (ms) to reach the batsman after being released from the bowler (Müller & Abernethy, 2008; Pinder, Renshaw & Davids, 2009; Taliep, Gibson, Gray, Van Der Merwe, Vaughan, Noakes, Kellaway & John, 2008; Weissensteiner, Abernethy & Farrow, 2011).

When a batsman plays a shot such as the pull or the hook, the bat is swung in a horizontal arc, perpendicular to the trajectory of the approaching ball. The batsman is required to judge the vertical position of the ball to within approximately three centimetres (limited by the bat’s width) and its time of arrival to within three milliseconds (limited by the time taken for the ball to pass the striking zone of the bat) (Land & McLeod, 2000; Weissensteiner *et al.*, 2011). The shot culminates when the batter attempts to make bat-ball contact using a defensive or offensive shot. The spatial and temporal difficulty of the task is amplified when the ball is delivered with ‘swing’ (i.e., curved trajectory), spin (i.e., such that the ball bounces off the ground to the right or left), and/or at high speeds. In addition, cricket balls change speed when they bounce, decelerate as they approach the batsman, and travel in an arc, meaning that it arrives at the batsman at varying heights (Land & McLeod, 2000; McRobert *et al.*, 2011), contributing to the difficulty of the task.

Furthermore, all types of bowlers purposefully vary the ball landing position (length). Balls delivered close to the batsman bounce lower while those landing further from the batsman bounce higher. The purpose of this variation is to change the height of bat-ball interception, which provides another challenge for cricket batsmen. A definitive forward movement of the foot is required to a ball of full length, and a backward movement to a ball of short length. When time constraints are imposed upon the batsman through high ball speeds, forward and backward foot movements need to be decisive to allow for early body positioning (Müller *et al.*, 2009).

Another factor in cricket batting that can increase spatial and temporal uncertainty is how the surface of the pitch (the area between the two sets of wickets) affects the bounce of the ball. Since the pitch is subject to natural elements, its characteristics can become variable not only between matches but even throughout the duration of a match. These factors can create uncertainty for the batsman with a selection of shot type. For this reason, skilled batsmen attempt to hit the ball as close to the time and place at which the ball bounces in order to nullify the variable bounce and lateral deviation of the ball (Müller & Abernethy, 2008). Furthermore, in a study conducted by McLeod (1987), it was found that when attempting to strike a ball (projected from a machine) after sudden lateral deviation, a minimum of 200 ms was required to make an adjustment to bat positioning in response to the deviation.

All of these factors create a scenario in which the travel time of the ball from the point of release by the bowler to the intended point of interception by the batsman may be less than the combined simple reaction and movement time of the batsman (Murphy, Jackson & Williams, 2018). Therefore, the advance prediction of the delivery type (through the development of a continuous link between the perceptual and action systems) could be essential for successful bat-ball contact to be achieved (Müller & Abernethy, 2006; Stretch *et al.*, 2000).

2.3. **Anticipation**

2.3.1. Definition and Model of Anticipation

Due to the spatial and temporal constraints involved in dynamic interceptive sports, as well as the latency in the processing of sensory information into appropriate motor responses, performers must rely on information other than ball flight in order to initiate their response. Performers are therefore required to anticipate or make a ‘prediction’ of the outcome of the observed event (Loffing & Cañal-Bruland, 2017). This anticipation consists of a mental foreseeing of a future event based on the perception of the aim of a given activity. The use of anticipation makes it possible to program motor activities which correspond with the expected action-outcomes and to adjust and correct them before disturbances occur (Borysiuk & Sadowski, 2007). Athletes who are able to anticipate successfully are described as being able to ‘read the game well’, ‘demonstrate superior game intelligence’ or appearing to have ‘all the time in the world’ (Williams & Jackson, 2019). The process of anticipation can relate to both spatial and temporal aspects. Spatial anticipation answers the question of what will happen, while temporal anticipation enables the perception of the moment in time in which the event will occur (Borysiuk & Sadowski, 2007).

According to Schmidt and Wrisberg (2008), there are several stages of processing through which information passes from input to output. In the first stage, called stimulus identification, performers analyse the content of environmental information using a variety of sensory systems. Once this processing is complete, the result of this processing is passed to the second stage known as the response selection stage, in which a translation occurs between the sensory input the performer has identified and one of several possible options for a response to the stimulus. In the final stage (response programming stage), various processes are thought to occur. This includes retrieving the motor program needed for action; preparing the necessary musculature for contraction and preparing the postural system for the dynamics of the action to be produced. In relation to this model, the use of accurate anticipation (using advance information) makes it possible to omit the phase of response selection (See Figure 2.1) resulting in a reduction of the motor response time (Borysiuk & Sadowski, 2007).

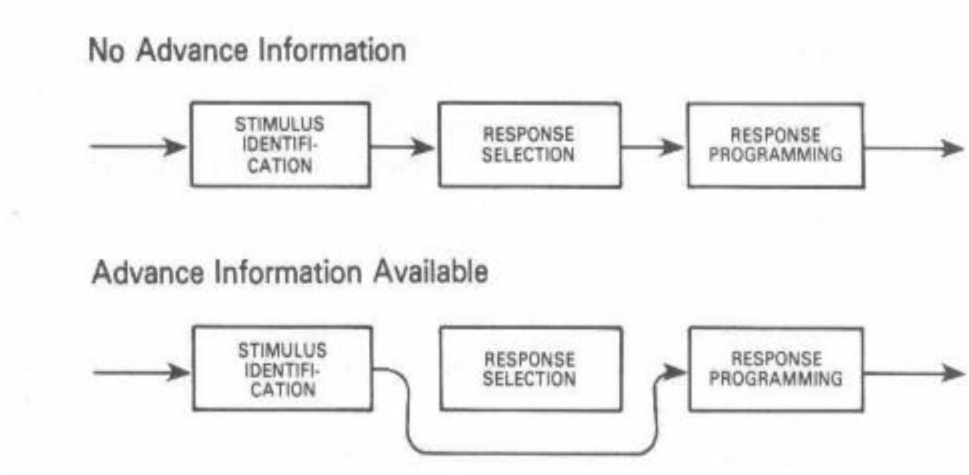

Figure 2.1- The stages of information processing with and without the use of anticipation (Borysiuk & Sadowski, 2007).

2.3.2. Anticipation and Decision-making

One characteristic of skilled performers is their ability to make decisions, which is an intricate process that occurs in complex situations and under severe time constraints. In this regards, the process of decision-making emerges from how attention, anticipation, and memory interact (Afonso, Garganta & Mesquita, 2012). Theories regarding decision making include the ecological approach (Gibson, 1979); Naturalistic decision-making (NDM) (Levi & Jackson, 2018) Take the First Heuristic (TTF) (Hepler & Feltz, 2012); and Recognition-Primed Decision (RPD) (Klein, 1993).

According to Ericsson and Kintsh, skilled performers have the ability to access and retrieve model situations through their knowledge stored in long-term memory (LTM) by the acquisition of long-term working memory (LTWM) skills. Moreover, these skills allow skilled performers to overcome the limitations of short-term working memory (STM) through the use of retrieval cues kept in STM that are associated with a response in LTM (Ericsson & Kintsch, 1995). Additionally, it is apparent that model situations are continuously updated with tactical information on the current situation (e.g., situational probability information) which can then be used to compensate actions and adjust decisions during the time-constrained tasks (McRobert *et al.*, 2011).

A traditional information-processing approach to cricket batting emphasizes that advance information from the preparatory movements of a bowler may be encoded, together with features of early ball flight. These advance cues are used by the batsman to perceptually anticipate the line, length and speed of the delivery. In an inferential process, these cues are compared to an internalized representation of the 'target' action (general motor program) already stored in memory from many similar situations. Finally, a decision is reached based on the available perceptual information, about whether there was a match with similar items in memory (Stretch *et al.*, 2000).

In the sport of cricket for each ball that is bowled, the captain needs to make a decision regarding the positioning of the fielders; the bowler needs to decide what type of delivery he is going to bowl, and the batsman needs to make a decision on what shot is going to be played. With this in mind, it can be said that decision-making is of utmost importance in the sport (Cotterill, 2014). According to the existing literature regarding decision making in cricket, there are numerous factors that influence an individual's decision making. These include the expertise of the performer (Renshaw & Fairweather, 2000); anticipatory skill (Müller *et al.*, 2006); the characteristics of the game (Thelwell, Weston & Greenlees, 2007); past experiences of a performer; the context of the game; the tactics employed by the team at that particular time of the game; the action capabilities of the individual; a performer's predisposition to act in a certain way; the strengths that the performer possesses; and individual differences of performers (Cotterill, 2011).

These influencing factors serve as the foundation on which decisions are made as they interact with the specific game situation and result in a particular course of action. The process of making decisions in the game of cricket has been described in four specific stages, not dissimilar to the information processing model described previously (Refer to Figure 2.1). In the first stage, known as the decision priming stage, a predetermined course of action is selected based on the context of the game or tactics of the team. For example, a batsman may stop and observe the field placements before preparing to face the next delivery (i.e., stimulus identification). In the next stage, a response is selected with the use of perceptual and environmental cues available such as the manner in which the bowler grips the ball. The penultimate stage of decision making involves the re-evaluation of the response. For example, the batsman may be required to modify the selected course of action based upon further perceptual information such as ball-flight characteristics. Finally, the performer evaluates the effectiveness of the selected action and uses this feedback for making decisions in the passage of play to follow. Using this type of information enables performers to construct a knowledge base for their opponent regarding effective courses of action (Cotterill, 2014).

2.3.3. The use of Anticipation in Sport

Since it has been well established in the sections above, performers face substantial spatiotemporal constraints in many dynamic sporting interactions, there is a need to anticipate future events in order to guide well-timed motor reactions (Williams, 2009; Müller & Abernethy, 2012). This includes the ability to predict an opponent's intention at an early stage of their movement (before obvious information regarding the movement outcome is available). In this regard, performers are thought to integrate both kinematic and contextual cues into their predictions. Therefore, it is assumed that anticipation is a process that is characterized by the continuous integration and sharing of information derived from current sensory input (e.g., visual perception of an opponent's movement) and prior knowledge or expectations (Loffing *et al.*, 2015).

In racket sports, success is largely attributed to the ability of a performer to anticipate events of the game. For example, tennis players may not be able to return an opponent's stroke if they do not anticipate correctly because their uncertainty may leave them insufficient time to return the shot. Therefore, it is important to predict the position of the ball's arrival well before it crosses the net (Crognier & Féry, 2005). In order to develop representative tasks that reflect the process of anticipation, it is important to identify the situations and constraints under which anticipation behaviours occur (Triolet, Benguigui, Le Runigo & Williams, 2013).

In a study conducted by Triolet *et al.* (2013), the nature and frequency of anticipation behaviours in professional tennis were quantified using video coding of incidents where the time delay between the opponent's stroke and the reaction of the performer was recorded. The authors argued that anticipation is based on uncertain information, which can lead to erroneous decisions, while reaction is based on certain information which results in a 100% response accuracy. In this study, it was found that a possibility is that anticipation occurs in very critical situations and the use of this strategy can enable players to win points that otherwise might have been lost. Furthermore, performers may decide not to anticipate if they perceive that there is enough time to react with the use of ball flight information rather than taking a risk by anticipation the opponent's response. Similarly, in competition, the costs of anticipating incorrectly may be far too great. This constrains performers to anticipate less-frequently, possibly only in situations where the chances of success are high or the costs associated with failure are tolerable (Williams, 2009).

The use of anticipation has been studied in multiple sporting codes including squash (Abernethy, Gill, Parks & Packer, 2001); tennis (Cañal-Bruland, van Ginneken, van der Meer & Williams, 2011); handball (Loffing & Hagemann, 2014a); karate (Milazzo *et al.*, 2016); soccer (Savelsbergh, Van der Kamp, Williams & Ward, 2005); volleyball (Loffing *et al.*, 2015); baseball (Müller, Fadde & Harbaugh, 2017) and cricket (Brenton, Muller & Mansingh, 2016). The vast amount of literature established that anticipation is a critical component of successful performance in time-constrained interactive tasks and that the advance pick-up of information from cues available before ball flight allows skilled performers to appear to 'have all the time in the world' (Müller & Abernethy, 2006).

2.4. Perceptual-cognitive Skills used in Anticipation

In order to cope with the spatiotemporal demands on dynamic interceptive actions, skilled performers rely on a variety of perceptual-cognitive skills to facilitate anticipation. Perceptual-cognitive expertise refers to the ability of an individual to identify and process environmental information for integration with existing and ongoing knowledge to facilitate response selection (Marteniuk, 1976).

Skilled action is not a spontaneous or random muscular response but is a representation of the final stage in a sequence of complex processes within the central nervous system (Elmurr, 2011). An important component of superior performance in many sports is the ability to make decisions when viewing complex, rapidly changing displays (North, Ward, Ericsson & Williams, 2011); while paying close attention to the most important perceptual information (Takeuchi & Inomata, 2009). Therefore it is necessary to integrate multiple sources of sensory data into a meaningful piece of information (Afonso, Garganta, McRobert, Williams & Mesquita, 2012; Farrow, McCrae, Gross & Abernethy, 2010), as well as the selection of an appropriate response (McRobert *et al.*, 2011).

Two broad categories of information sources can be differentiated to contribute to the anticipation, or prediction of action effects in sports: kinematics of the opponent and contextual (non-kinematic) sources of information (i.e., situational probability information). The efficient identification and use of these sources are important perceptual-cognitive skills and may be governed by different factors related to domain-specific expertise (Loffing & Cañal-Bruland, 2017). The following sections will highlight key findings from recent research on these two branches of information sources.

2.4.1. The Use of Kinematic Cues for Anticipation

Biological motion patterns contain information regarding identity, emotion, and intentions. For example, in the absence of obvious clues, it is possible to discern the gender of someone walking (Troje, 2002). Similarly, Huys, Smeeton, Hodges, Beek and Williams, (2008) used stick figure simulations of an opponent to show that skilled tennis players are able to predict, with a high degree of certainty, where an opponent will play the ball before it is actually hit. These skilled performers are more proficient in obtaining the relevant information from an unfolding action than less-skilled performers are (Huys *et al.*, 2008). Furthermore, goalkeepers in soccer are able to anticipate the likely direction of an opponent's penalty kick even before the ball is kicked. They do this by observing the movements of the kicking leg, supporting leg, as well as the kicker's hips which provide clues about where the ball is likely to be directed (Savelsbergh *et al.*, 2005).

Hitting actions in racket sports, as well as all overarm throwing patterns, have systematic and quantifiable biomechanics (Abernethy *et al.*, 2001). In most fast-ball striking sports, the deterministic nature of the biomechanics of the opponent's movement pattern means that intent must be clearly specified by the kinematic properties of his or her action, at some point before ball release (in sports such as cricket and baseball) or opponent's ball contact (in sports such tennis and squash) (Abernethy *et al.*, 2001). Looking in the correct place at the correct time in ball sports such as tennis, cricket and baseball is of high importance. In these sports, performers are required to determine the future trajectory of the ball as well as time their movements to make successful contact (Land & McLeod, 2000). As the opponent's action progresses, sources of specification that are systematically more informative for predicting the action become available. This results in a trade-off between the degree of specification such information can provide, and the time of information availability (Müller & Abernethy, 2012).

Furthermore, it has been suggested that pre-ball-flight kinematic information is important for appropriate gross body positioning in time-stressed interceptive tasks, with ball flight necessary for the fine motor adjustments necessary for successful interception. For a task like cricket batting, this would suggest that the kinematic information available before ball-release may be more useful for lower-body positional movements (i.e., moving onto the front-foot or back-foot before playing a shot), while the ball flight information is useful for upper-body movements needed for bat-ball contact (Mann, Abernethy & Farrow, 2010).

In the sport of cricket, skilled batsmen are able to select their shots using a number of early sources of information to which lesser-skilled batsmen are not attuned. According to Cork, Justham and West (2010), these skilled batsmen have been found to possess key abilities which are developed within their anticipatory skill including:

a) Visual search- selecting the areas upon which the eyes will focus during the delivery stride and release;
b) Selective attention- selecting the most important elements within the action of the bowler that relate to the type of delivery;
c) Discrimination ability- recognizing the movements of the bowler and the ability to interpret them into the delivery type resulting from these movements.

2.4.1.1. Kinematic Information Pick-up Strategies in Skilled Anticipation

It has been well established that the use of kinematic cues for anticipation is an important perceptual-cognitive skill. However, it is also of interest to understand what strategies are employed by skilled performers while using kinematic information.

The extant literature indicates that successful anticipation is based on the pick-up of dynamic kinematic information (Cañal-Bruland *et al.*, 2011) and that skilled performers employ a more effective search strategy to pick up information and are better able to infer an opponent’s action intentions based on advanced cues which emanate from their kinematics before a critical event (Müller & Abernethy, 2006; Weissensteiner, Abernethy, Farrow & Müller, 2008; Rosalie & Müller, 2013; Loffing & Hagemann, 2014b; Mann, Schaefers & Cañal-Bruland, 2014). Skilled anticipation in striking sports appears to be related to the kinematic information available in the visual display. Skilled performers are more superior to less-skilled performers in that they are more attentive to the function relating the time of information available to the degree of specification of the movement pattern perceived. As a performer becomes more skilled, he or she acquires the perceptual information earlier to support a given level of specification and a greater degree of specification provided by any temporal sample of the total movement (Müller & Abernethy, 2012). The greatest specification of the event being viewed, and greatest constraint on the movement response to be executed undoubtedly arise from ball flight information. Late kinematic as well as early ball flight information my synchronously allow the performer's striking action to progress "just in time" and with spatial orientation required to achieve optimal interception (Müller & Abernethy, 2012).

A number of cricket-related studies have demonstrated that skilled adult batsmen have a higher prediction accuracy of ball direction and delivery type from the pre-release movement patterns of both slow (spin) and fast (pace) bowlers (e.g., Müller *et al.*, 2006; Renshaw & Fairweather, 2000). In fact, the ability to discriminate perceptually subtle differences in bowling technique of skilled wrist-spin bowlers is thought to be a key factor in predicting batting success (Renshaw & Fairweather, 2000).

While researchers agree that movement patterns provide sufficient information for anticipation, it is highly debated as to whether this information is picked up globally or from local kinematic sources (Cañal-Bruland *et al.*, 2011). It has been suggested that the kinematic cues informing skilled anticipation as well as the predictive role of certain body areas are likely to vary across sports (e.g., throwing and striking sports, and racket sports) and even between tasks within the same sport (Loffing & Cañal-Bruland, 2017).

In order to investigate this issue, Williams and colleagues used point-light display to manipulate specific body regions (e.g., shoulder, hips, arm-racket area) of an opponent hitting forehand tennis strokes and presented the actions as point-light animations stopping at the moment of racket-ball contact. In this format, opponent's movements are visually reduced to its underlying motion (Loffing & Cañal-Bruland, 2017) using points of light that are presented corresponding to the anatomical locations of the body (e.g., shoulders, elbows, hips, and knees) against a dark background. Results indicated that skilled tennis players relied on different body areas compared to their less-skilled counterparts, who were found to rely mainly on the arm-racket area. Therefore, skilled performers were supposed to use a global information pick-up strategy as opposed to less-skilled performers who rely primarily on local end-effector information (Williams, Huys, Cañal-Bruland & Hagemann, 2009). Similarly, Huys and colleagues reported that differences in tennis shots to various locations are present across the entire body and that skilled observers rely on a more global perceptual approach and making use of information other than that related to the end-point of the movement (Huys, Cañal-Bruland, Hagemann, Beek, Smeeton & Williams, 2009).

In contrast, a study in cricket batting by (Müller *et al.*, 2006) suggested that skilled batsmen were found to be superior to less-skilled batsmen in anticipating delivery type before ball release, indicating that they could effectively extract early information, particularly from the motion of the bowling arm and hand. Later on, Müller and colleagues (2010) built on their previous work and used video-based temporal and spatial occlusion methodologies to examine expertise-related differences in anticipatory information (Müller, Abernethy, Eid, McBean & Rose, 2010). In the temporal occlusion approach, the advance information from the preparatory movements of the opponent is simulated using film or video and vision of the movement pattern is occluded during selected time periods before, at, or after the release of the ball (Müller & Abernethy, 2006). Performers are required to anticipate the opponent's action or the outcome of the action by either responding verbally, using pen and paper or by physically performing an action response for the stimuli presented (Ford, Low, McRobert & Williams, 2010). In the spatial occlusion method, specific sources are occluded or hidden (for example by using a black patch) during the video sequence in order to identify the visual cues in the display which are most informative (Hagemann, Strauss & Cañal-Bruland, 2006). Cricket batsmen were shown video displays of a bowler delivering one of three different delivery types. The display was manipulated so that only selected local features of the bowler's movement pattern (e.g., bowling hand) were visible and then only for specific time periods prior to ball release. It was found that information from bowling hand and arm cues was especially critical, although continuous visibility of these cues was seemingly not vital for information pick-up. Muller and colleagues argued that a key element of batting success is the ability to selectively attend to only the pertinent local sources of information, and avoid processing irrelevant, distracting, or deceptive cues at a more global level, present within the bowler's movement pattern (Müller *et al.*, 2010).

Similar findings regarding the use of a local information pick-up strategy were found in tennis (Cañal-Bruland *et al.*, 2011); handball (Loffing & Hagemann, 2014a); badminton (Abernethy & Zawi, 2007); baseball (Takeuchi & Inomata, 2009); and again in cricket (Müller & Abernethy, 2006). Furthermore, the body areas linked to successful anticipation have been implemented into sport-specific training of perceptual-cognitive skills. These interventions have been used to improve less-skilled performer's abilities to predict an opponent's action-outcomes (Loffing & Cañal-Bruland, 2017). For example. Hagemann and colleagues used a transparent red patch on video clips of badminton players during overhead shots of an opponent to orientate attention towards key stimuli such as the trunk, arm and racket of the opponent. Results indicated that less-skilled badminton players who trained using this technique significantly improved their anticipatory skill between post- and retention tests compared with controls (Hagemann *et al.*, 2006). This means that these types of methods can be employed to foster talent development in sports (Loffing & Cañal-Bruland, 2017).

It is important to note that Williams *et al.* (2009) claimed that skilled performers used a global rather than local search strategy, but acknowledged that the arm and racket were particularly informative when predicting the shot direction in tennis. It appears that local kinematic information is vital to skilled anticipation, however, the search strategy employed by skilled performers could be dependent on the type of sport as well as the intentions of the performer.

While anticipation of the intentions of an opponent is essential for the performer, the use of deception (presentation of false visual cues) and disguise (delayed display of an informative cue) are important strategies used by skilled opposition to blunt the effects of correct anticipation (Brault, Bideau, Craig & Kulpa, 2010). The use of postural cues as a way of faking an action intention has been shown in a variety of sporting codes including rugby (Jackson, Warren & Abernethy, 2006), tennis (Rowe, Horswill, Kronvall-Parkinson, Poulter & McKenna, 2009), basketball (Güldenpenning, Kunde & Weigelt, 2017), and handball (Cañal-Bruland & Schmidt, 2009). In many interactive sports, deceptive actions are common and recently, researchers have studied the ability to judge deceptive intent (Williams & Jackson, 2019).

For example, Kunde and colleagues investigated the cognitive processes that underpin the effect of kinematic deception in basketball. Less-skilled basketball players were required to decide as fast as possible whether an opposition player would pass the ball to the left or to the right after viewing an image of their opponent on a computer screen. The opponent’s head and gaze were orientated in the direction of an intended pass or in the opposite direction. It was found that turning the head in the opposite direction to which the pass was delivered in basketball negatively impacted the ability of the defender to judge the direction of the pass (Kunde, Skirde & Weigelt, 2011). However, skilled performers are still able to make use of late arising kinematic information to make judgements above chance, even when deception is taking place (Rowe *et al.*, 2009).

Research has shown that differences between skilled and less-skilled performers are sometimes much larger for judgements of deceptive actions than genuine actions (Brault *et al.*, 2010). Therefore, the ability to distinguish between relevant and irrelevant kinematic information through selective attention is essential for successful anticipation (Müller & Abernethy, 2012). Anticipation provides a means for the performer to guard against deceptive actions or strategies of an opponent (Müller *et al.*, 2009).

While most of the existing knowledge surrounding expert sporting anticipation stems from various types of video simulations, one concern is that such approaches may not present a complete understanding due to the removal of the skill from its natural setting; the removal of the need and opportunity for interception, and the de-coupling of the perceptual and action elements of the skill (Müller & Abernethy, 2012). Although these laboratory-based occlusion studies have been useful in providing knowledge about perceptual expertise in sports, these methodologies have a number of significant limitations. First, video-based experiments provide a less than perfect display of the perceptual information of the natural world. This means that there could be degradation of a number of possibly critical elements of the perceptual array. There is also a loss of stereoscopic depth information, reduction in the visual field and image size, and a loss of some display resolution. Second, it is difficult to reproduce in the laboratory setting the time stresses that exist in responding in the natural task, especially in paradigms that require a simple verbal or written response. Finally, the laboratory tasks present each stimulus pattern-response option with equal probability, thus removing situational probability as a potential source of anticipation information (Abernethy *et al.*, 2001; Crognier & Féry, 2005). Furthermore, video-based temporal occlusion techniques which do not require actual object interception are inherently biased towards the ventral vision-for-perception stream, while this stream and the dorsal vision-for-action stream are integrated during skilled performance in the natural skill setting (Van der Kamp, Rivas, Van Doorn & Savelsbergh, 2008). For a more in-depth explanation on the dorsal and ventral streams, see the work of Milner and Goodale (2008).

A number of investigations of striking skills have been conducted in natural settings in to keep the usual coupling between perception and action in order to minimize some of the limitations involved with simulation approaches in the laboratory (Müller & Abernethy, 2012). Recently, there has been an increase in interest in advancing the understanding of expert interceptive timing skill in sport through the use of in-situ tests. This is because an in-situ test is more similar to the real-world performance context of the motor skill than video simulation and virtual reality tests. For example, Müller and colleagues investigated the timing of information pick-up for interception by cricket batsmen of different skill levels. In their study, batsmen were required to strike delivered balls while their vision of the bowler’s delivery action was occluded at several different stages through the use of occlusion goggles. Foot movements of the batsmen were used to assess ball length judgement, while the quality of bat-ball contact was assessed as a measure of interception (Müller *et al.*, 2009).

However, an in-situ test can create several methodological and logistical challenges during the planning and implementation of an experiment (Müller *et al.*, 2015). Müller and colleagues (2015) defined *in-situ* in terms of sport research as (a) an experimental test that is conducted in settings such as a performance laboratory or the actual sport skill setting such as a volleyball court; (b) where a performer competes against an opponent authentic to the sport skill setting; (c) where the object to be intercepted is delivered by the opponent to the performer at a similar speed (safety permitting) with those experienced in the sport skill setting; and (d) where visual-perceptual information occurring both prior to and during object flight is available to the performer to guide physical movements to intercept an object. Collectively, the body of literature that has used an in-situ test has indicated that to be able to efficiently intercept a fast-moving object such as a baseball or cricket ball, the capability to anticipate as well as coordinate body segments are vital for an interceptive skill (Pinder *et al.*, 2009).

2.4.1.2. Ball-projection Machines vs Opponent

An important experimental strategy in research on interceptive actions has been to manipulate properties of environmental information in order to observe any changes in the organization of participant's movement responses, as expressed in movement kinematics. It is assumed that any changes to observed movement kinematics are likely to be due to experimental manipulations of perceptual variables (Jacobs & Michaels, 2010). Therefore, it is important to understand how changing the perceptual information available in practice environments constrains the performance of interceptive actions. For example, in ball games such as baseball, tennis, field hockey and cricket, ball projection machines are useful for aiding practice strategies of task decomposition that allows a specific movement, such as batting, to be practised away from the constraint of a competitive game. A ball projection machine also allows for an accurate and consistent projection of balls to learners practising a specific movement (Renshaw, Oldham, Davids & Golds, 2007).

In cricket, while the use of a bowler would provide a task more representative of game conditions, bowling machines produce more control and less variation in terms of ball speed and placement (Croft, Button & Dicks, 2010). While batting, most pre-flight information is obtained from visual cues during the bowler's delivery. A key issue with traditional projection machines is that they do not provide advance cues, which are vital for anticipation and coordination in interceptive skills (Müller *et al.*, 2015). Performers, therefore, need to rely on other sources such as early ball flight information to time and organise their movements. It is believed that these cues are far less useful than those gained from the kinematics of the bowler which results in a different technical response from the batter (Peploe, King & Harland, 2014). Furthermore, research has shown that the movement coordination of both skilled (Renshaw *et al.*, 2007) and less-skilled (Pinder *et al.*, 2009) cricketers in response to bowlers is significantly affected by training practices using bowling machines. The loss of the advance information provided by the bowler alters the organization and control of the movement response to the point that timing and coordination dynamics in the two tasks become quite different and performance in the absence of advance information is a poor predictor of performance in the natural skill (Müller & Abernethy, 2006). Additionally, attempts to train anticipation by creating variation in ball length and type through changing the angle of projection and spin speeds of the rotating wheels of the ball projecting machines are too obvious and easily detected by the batsman (Müller & Abernethy, 2008).

In the study conducted by Renshaw and colleagues (2007), the movement timing and coordination of the forward defensive stroke in cricket batting were examined in skilled batters under two typical practice conditions: batting against a representative "real" bowler and a representative bowling machine. Significant re-organization in timing and coordination was found under the different task constraints (i.e., bowling machine and bowler). For instance, when facing the bowler, initiation of the backswing was later while when facing the bowling machine, downswing was faster with a different ratio of backswing-downswing (47%-53%) compared with the bowler (54%-46%). Additionally, peak bat height was lower and the mean length of front foot stride was shorter when facing a bowling machine. This shorter step meant that the batter did not get as close as possible to the bounce of the ball, failing to limit the amount of any possible lateral deviation of the ball after it pitched. Taken together, these findings suggest that practising under the ecological constraints of a bowling machine can lead to the development of coordination patterns and timing different to when batting against a real bowler. These results, in terms of differences in movement coordination, were supported by similar studies by Pinder *et al.* (2011) and Peploe *et al*. (2014) in cricket, and Shim, Carlton, Chow and Chae (2005) in tennis.

2.4.1.3. Visual Search Behaviour

In sport, perceptual-cognitive motor skills are performed in environments in which there is often variation in visual information. This necessitates the ability of performers to adapt in order to achieve the action goal (Müller *et al.*, 2017). The ability of performers to pick up advance visual cues is partly related to the manner in which they move their eyes around in an attempt to extract the most vital information (Williams, 2009). These visual search behaviours in dynamic sport settings are typically examined using a head-mounted eye-tracker using corneal reflection technique (Williams, 2009). A meta-analysis on eye-tracking research suggests that skilled performers make use of an efficient visual search strategy by directing their gaze to information-rich areas, using fewer fixations of longer durations. This is not necessarily specific body parts but also regions that enable information pick-up of the surrounding gaze location (Mann, Williams, Ward & Janelle, 2007).

When attempting to intercept a fast-moving projectile, it has been assumed that humans are required to fixate on the trajectory of the object to be intercepted (Regan, 1997). However, in many fast ball sports, this pursuit tracking is often too slow, especially when projectile velocity approaches 100˚/s. Furthermore, in many fast ball sports such as cricket and squash, the performer is required to track a ball with rebound characteristics (due to the bounce) which are difficult to predict in advance (Croft *et al.*, 2010).

In a study conducted by Golby (1989), 10 experienced cricket batsmen attempted to hit balls delivered from a ball projection machine, at a pace equivalent to fast-medium bowling (approximately 80km/hr). In this experiment, the vision of sections of the ball's flight was selectively prevented with a system of wooden screens. Results of batsmen's response accuracies showed that the middle section of ball flight, rather than early or late ball flight, was most vital to successful batting performance. Golby suggested that this may be because this section of the ball flight is important for determining the accuracy of an initial prediction of the landing position of the ball based on pre-release information (Golby, 1989).

Elite cricket batsmen are highly focused on a number of sources of information that aid in selecting their forthcoming shot. By identifying these visual cues, batsmen are able to perceive pre-flight information regarding the future trajectory of the delivery, thus allowing them to begin their movements prior to ball release (Müller & Abernethy, 2006). In cricket, this ability to predict the trajectory, velocity and arrival point of the ball using anticipation appears to be of high importance for skilled batting for a number of reasons. Earlier initiation of processing of visual information from sources other than ball flight can provide more time to complete the required response, hence overcoming the reaction time delays. Furthermore, anticipation can facilitate the earlier initiation and completion of gross body movements (i.e., stepping movements of the feet), so that a more balanced base of support can be created to allow for superior timing of the shot (Müller & Abernethy, 2008). Müller and Abernethy (2012) proposed a preliminary two-stage model of skilled anticipation in striking sports. This model proposes that kinematic advance information from the opponent can be used by skilled performers to guide the lower body movements while the information made available during ball flight can guide movements for the interceptive phase of the action.

The information processing paradigm assumes that knowledge of skilled performers' visual fixation points can be used to model their pick-up of information. However, because skilled performers may use peripheral and not only foveal vision to control their behaviour, the full knowledge of gaze behaviour does not provide complete information on which stimuli are actually perceived (Hagemann *et al.*, 2006).

Some preliminary evidence of factors that contribute to effective interception was provided by Land and McLeod (2000). More specifically, the authors reported that a skilled and a less-skilled batsman made use of pursuit tracking during early ball flight in order to gauge its trajectory, before initiating a saccade to the anticipated landing position of the ball (the length of the delivery) earlier during the ball's flight phase than a weaker amateur. Additionally, the authors reported that it is not possible to pursuit track a fast-moving cricket ball, but rather an anticipatory saccade was made to predict the future landing position of the ball.

In certain instances, it is possible that performers may rely exclusively on the ability to process information coming from an opponent's postural orientation (e.g., a goalkeeper facing a particular penalty taker for the first time), yet under more dynamic and severe time constrain situation such as open play, it is likely that different perceptual-cognitive skills interact with each other in a changing fashion to facilitate more accurate anticipation and decision making (Roca & Williams, 2016). Afonso and colleagues combined verbal reports of thinking and eye movement records to examine the process underpinning perceptual-cognitive expertise in an in-situ volleyball task. Skilled volleyball players performed as defenders in simulated sessions while wearing an eye-tracking device. After each sequence, players were questioned regarding their perception of the situation. Results indicated a connection between visual search and a more sophisticated knowledge base (Afonso, Garganta, McRobert, *et al.*, 2012). This knowledge base possessed by these skilled performers provides the framework from which situational probability information is derived. The use of this situational probability information is another important perceptual-cognitive skill used to facilitate anticipation and will be discussed in the next section.

2.4.2. The Use of Situational Probability for Anticipation

As previously discussed, success in fast ball sports is generally attributed to the ability to anticipate game events successfully, and performers are thought to learn how to use two essential and related sources of information to help them predict future events. The first source of information is the movement pattern of the opponent, while the second is prior knowledge of probable upcoming events (Runswick, Roca, Williams, McRobert & North, 2018a). This second source of information may enable the performer to predict events by making it possible to dismiss many events as highly improbable (Crognier & Féry, 2005).

Probabilities allow us to quantify future events and are an important aid to rational decision making (Levitin, 2016). Knowledge of likelihoods or probabilities about certain events occurring had early been shown to influence a performer's anticipatory movements, even before their opponent's movement information is revealed (Loffing & Cañal-Bruland, 2017; Murphy *et al.*, 2018). For example, game aspects such as the pitch count or the number of batters on each base provide advance cues in baseball as to the likely type of pitch to follow as well as its location relative to the strike zone (Gray, 2002). Similarly, the placements of fielders in cricket may provide a clue to the bowler's intent before the ball is actually delivered (Müller & Abernethy, 2012).

Research on probability information in sport was pioneered by Alain and colleagues, who indicated that racket-sport players used their task-specific experience to assign probability scores to events likely to occur in any given situation. Participants were presented with a computer-simulated game vision of themselves in rally situations against an opponent. A confidence rating was provided by the participants after rating the likelihood of an opponent's shot, and an allocation of how much their own initial movement response was guided by this probability was made. Results revealed a strong relationship between the performers' subjective assessment and the subsequent anticipatory movements (Alain & Proteau, 1980).

More than twenty years later, Abernethy *et al.* (2001) showed that probabilistic information that they termed situational probabilities could be used to anticipate action-outcomes in the absence of an opponent's movement information. Abernethy and colleagues investigated whether uncertainty is reduced by the contribution of anticipation with the use of situational probabilities. Occlusion goggles were used for squash players during simulated match play. These goggles worn by the performer are triggered by the researcher to occlude the performer's vision at various time points in the skill performance of the opponent and are used to examine the timing of visual behaviour (Müller *et al.*, 2015). Six skilled and six less-skilled male squash players were required to play against an opponent on a squash court and to make movements in response to a sequence of events when their vision was occluded. The skilled performers were better than their less-skilled counterparts in predicting the direction and depth of the opposing player's stroke, as early as 600 ms prior to the opponent's racket-ball contact. The authors concluded that an accurate knowledge of situational probabilities may have facilitated successful anticipation even before any significant preparatory movement had been made by the opponent, and that situational probability information adds value to that obtained from current information sources such as ball flight information and an opponent's movement characteristics.

Since then, there has been an increase in interest in the contribution of situational probability information to anticipatory behaviour. This includes the impact of probabilistic information such as patterns related to game score (Farrow & Reid, 2012); exposure to an individual's action preferences (Mann *et al.*, 2014); exposure to previous sequences of an outcome (Loffing *et al.*, 2015); the manner of interaction between an opponent's court position and kinematically driven judgements (Loffing & Hagemann, 2014b); how availability of contextual information affects gaze behaviour (McRobert *et al.*, 2011) and the cognitive processes that underlie anticipatory skill (Murphy, Jackson & Williams, 2015). Runswick and colleagues differentiated between two types of context. Situation-specific contextual information relates to sources which are changeable and unique to that specific event such as game score and opponent positions, while non-situation-specific contextual information pertains to those which are more stable, such as a team's past performances and playing style (e.g., action preferences) (Runswick, Roca, Williams, Bezodis & North, 2017). These types of situational probability are used by skilled performers to build a knowledge base that is stored and retrieved from long term memory and is updated on a regular basis based on their own performances and that of their opponents (McPherson, 2013).

2.4.2.1. Sources of Situational Probability Information

2.4.2.1.1. Pattern Recognition

While the vast majority of research focusses on important cues and the time that the cues are extracted from the environment, other perceptual-cognitive skills have been identified as playing a role in anticipation. One important skill is the ability of performers to identify patterns in evolving sequences of play (Williams & Jackson, 2019). The importance of pattern recognition was emphasized by a study in basketball, where a video recording of a competition as well as verbal report information was used to understand how skilled basketball players interpreted match situations. It was found, through verbal report data, that players considered teammates' and opponents' positioning and moves while assessing the situation and anticipating the development of play (Macquet & Kragba, 2015).

The importance of understanding the opponent's positioning in sport was further emphasised in a study by Loffing and Hagemann (2014), where it was shown that shot-direction probabilities vary as a function of a hitting performer's on-court position in professional tennis. The authors first assumed that the spatial layout of a tennis court and resulting constraints on the stroke outcome (e.g., error variance) would make performers preferentially play cross-court shots as opposed to down-the-line shots, especially when hitting balls from near the side-line. Skilled and less-skilled tennis players watched tennis strokes of an opponent presented as point-light display in videos and were asked to predict the outcome of an opponent's forehand baseline shots by pressing keys on a computer keyboard. It was revealed that skilled performers, in contrast to less-skilled performers, were more susceptible to positional information when anticipating these shots. In addition, the further away the opponent was from the midline during shot execution, the more skilled performers expected him to play a cross-court shot and the position dependency in skilled performers' expectations was evident early in the opponent's shot sequence. It was suggested that knowledge obtained through extensive training and competition made skilled performers more aware of positional information and helped them to include this information into their anticipatory decisions. It was speculated that the pattern observed in skilled performers may indicate a Bayesian strategy. Following this strategy means that domain-specific (prior) knowledge is continually integrated with incoming sensory information (likelihood). Each step of these mental determinants results in updated expectancies, which then serve as a new prior in the subsequent step of combinations with new sensory information. Using Bayesian probabilistic inference, the performer aims to reduce the total uncertainty associated with hidden variables (in this case, the delivery outcome) (Vilares & Kording, 2011). This process suggests that if one informational variable is associated with greater uncertainty than the other, the combined probability distribution should be biased towards the less uncertain variable (Knill & Pouget, 2004). The more one has to act under uncertainty, the reliance on prior information is assumed to be strongest (Körding, 2007; Wolpert & Flanagan, 2010).

In order to determine the sources of information facilitating skilled pattern recognition and recall, some researchers have manipulated the information they present to participants. Williams and colleagues manipulated videos of sequences from soccer matches in a way that they were presented in either static or dynamic format and then presented videos in which central or peripheral elements were absent from the dynamic display. Soccer players were presented with these stimuli as well as new stimuli and were required to indicate as to whether or not each sequence had been presented earlier. It was found that skilled performers were more effective in recognizing patterns of play when viewing dynamic clips compared to static images and clips where frames were presented in a random manner. The authors suggested that a vital mechanism for skilled pattern recognition is the effective extraction of motion information and only the relative motions of a few key features are necessary for effective recognition of domain-specific patterns (Williams, North & Hope, 2012).

However, not all research supports these results. Pattern recall performance in skilled and less-skilled basketball players was measured by examining the spatial error in recalling player positions using static and dynamic video test stimuli. The basketball players were required to recall the final positions of each of the attacking and defending players in the test stimuli by using a computer mouse. It was found that pattern recall error was lower and decision-making accuracy higher when viewing a static display than a dynamic display in basketball plays (Gorman, Abernethy & Farrow, 2013).

In cricket, the predetermined course of action that is selected is based upon the context of the game, team tactics, and a response to what the opposition is doing at any point of the game. For example, a batsman may stop and look around at the fielding positions before preparing himself for the subsequent delivery (Cotterill, 2014). The relative importance of these fielding positions in cricket was investigated by Runswick *et al*. (2018a) while examining the effect of congruence between contextual information and event outcome in anticipation in cricket. In this study, skilled cricket batsmen were required to predict the location of a delivery from a video-based test stimulus, based on the game situation and field setting which was displayed prior to each delivery on the screen. A delivery was deemed congruent if the ball location was tactically appropriate for the game situation and field settings. In contrast, an incongruent trial was one in which the delivery outcome was not tactically appropriate for the game situation and field setting. In terms of situational probabilities, most researchers have mainly focused on situations in which the information presented to participants is congruent with the event outcome (i.e., the information presented in the form of an opponent's kinematics and the situational probability information leading to a probable outcome). However, in many sporting scenarios, it is likely that the kinematic and contextual information presented may be incongruent with the event outcome, which means that deception is involved. For example, fielders in cricket are located based on tactical plans that intend to increase the chances of getting the batter out and decrease the likelihood of runs being scored.

The bowler will attempt to deliver the ball to bounce in a location that is appropriate for the placement of the fielders. The information available to the batter is congruent if the game context (field placement) and bowler's kinematics both lead to the subsequent delivery location. However, bowlers can execute deliveries that land in a location that differs from that which may be predicted from the kinematic or contextual information presented. This can be through either deliberate deception or through poor execution (a bad delivery) and results in information which is incongruent with the eventual outcome (Runswick *et al.*, 2018a). Results showed that the skilled cricket players anticipated significantly more accurately than the less-skilled group on the congruent trials and that both groups anticipated less accurately on incongruent trials, with the skilled participants being more negatively affected.

It was suggested that skilled performers understand the importance of situational probability information and that confirmation bias affects the use of kinematic cues available later in the action. Confirmation bias suggests that once a decision has been made, people prefer to rely on supporting information and avoid information that conflicts with that presented originally (Jonas, Schulz-hardt, Frey & Thelen, 2001). If skilled batters develop outcome expectations based on contextual information early in the process of anticipation, this could lead to confirmation bias and influence the use of kinematic cues which are available later in the process. In congruent situations, anticipation is generally more accurate as a judgement is made based on contextual information and supported with later arising kinematic information. However, in incongruent situations, the kinematic information may not be used as it suggests an outcome that is in contrast with the original decision, leading to a lower accuracy in anticipation. Furthermore, the negative effects of confirmation bias could be intensified by skilled batsmen relying more heavily on sources of contextual information than less-skilled counterparts. Consequently, less-skilled performers, while more likely to be deceived by kinematic cues, are less likely to be a victim of confirmation bias and deception caused by contextual information (Runswick *et al.,* 2018a).

2.4.2.1.2. Action Preferences

In many sporting scenarios, individual performers can have a bias in the type of action that they perform, even though this action may not offer any competitive advantage. For example, there should be no specific advantage in directing a penalty kick in soccer towards any particular corner of the goal if both the goalkeeper and the kicker are standing in the centre of the goal. However, performers may still have their own individual action preferences in these situations, meaning that there is a potential bias in the relative distribution of their preferred actions. These action preferences may be due to greater effectiveness of performing one motor action over others, and/or because of the performer's previous success when performing that action (Mann *et al.*, 2014).

For instance, an analysis of ball placement data for professional tennis by Loffing and colleagues found that overall, right-handed players faced considerably more forehand cross-court shots against left-handed players as opposed to right-handed opponents. Therefore, when confronted with a left-hander, a right-handed player might expect their opponent to play preferential forehand cross-court shots towards the right-hander's backhand (which is often assumed to be weaker than the forehand) (Loffing, Hagemann & Strauss, 2010). Similarly, in baseball, the batter's current model of the pitcher based on situational information can be updated based on their previous pitching tendencies, strengths and weaknesses, and how they changed according to the situation of the game and the specific style of the current or previous batters. The batter could use this contextual information to develop specific response strategies based on the profile of the pitcher and continuous monitoring of their own performance (McRobert *et al.*, 2011).

A study of this phenomenon conducted by Mann *et al.* (2014) investigated how exposure to action preferences of an opponent can influence the ability of skilled handball goalkeepers to anticipate the action-outcome of the opponent. Two groups of skilled handball goalkeepers were required to anticipate the direction of an opponent's penalty throws, before and after a training intervention, using a computer keyboard after watching a temporally occluded video of the opponents. During the training intervention, the goalkeepers in the action preference training group viewed the action-outcomes of two opponents who had a preference to shoot in one particular direction, while goalkeepers in the non-action preference training group viewed players who threw equally in all directions. It was revealed that handball goalkeepers who were exposed to opponents who possessed an action preference improved in anticipatory performance if the opponent continued to bias their shots towards their preferred direction but decreased in anticipatory performance if the opponent did not. Similar studies have been conducted in soccer, where it was not only found that goalkeepers' anticipation performance was better under conditions where the opponent had an action preference, but their initial movement time was also earlier under this condition (Navia, Van der Kamp & Ruiz, 2013).

These results suggested that skilled performers make use of action preference information to improve their anticipatory ability. However, it was clear that doing so can be disadvantageous when the outcomes are not consistent with the expectations that are generated. Therefore, two critical issues that should be considered which suggest that the knowledge of opponents' action preferences is not always beneficial. First, it is possible that explicit guidance about the likely outcome of an action could be a disadvantage as it has the potential to distract skilled performers from making the types of well-learned responses that they are accustomed to performing (Mann *et al.,* 2014). Skilled performers develop their level of expertise by using advance kinematic information to guide their motor responses (Shim *et al.*, 2005). Therefore, by drawing attention toward particular action-outcomes, this additional information may distract the skilled performers from using the kinematic patterns that they would usually rely on to anticipate action-outcomes.

The second issue to consider is that this information about action preferences may be a distinct disadvantage if there is incongruence between the expected and actual actions performed by the opponent (Gray, 2002). In other words, if the expected outcome is in conflict with the advance kinematic information then it can be expected that the information about action preferences may harm rather than support anticipatory performance (Mann *et al*., 2014; Runswick *et al.*, 2018a). This was found to be the case in the above-mentioned study conducted by Mann and colleagues (2014), where it was also found that the act of becoming aware of explicit information in itself may have interrupted automatic (implicit) processes that are characteristic for skilled performers. Additionally, if the explicit information about action preferences is inconsistent with the kinematic information picked up during the throwing action, this information could harm rather than help performance (Mann *et al*., 2014).

2.4.2.1.3. Sequencing of Action-outcomes

Another source of situational probability information in sport is the presence of a sequence in the action-outcomes of an opponent. The idea of utilizing attack sequences to anticipate an opponent's intention was investigated by Milazzo *et al*. (2016), in the sport of karate. Skilled and less-skilled karate fighters were required to make decisions regarding various opponent attacks in different in-situ fight scenarios. The order in which the fight scenarios were presented was changed to provide advanced probability information. Specifically, one of the attacks was repeated every four actions. Response accuracy and initial movement time of the fighters were used together with eye-tracking technology and verbal report information to provide a deeper understanding of the perceptual-cognitive skills utilized. Results showed that skilled performers were able to able to pick up the occurrence of an attack pattern after the fifth repetition, whereas less-skilled performers did not. This could mean that skilled performers used a more efficient visual search strategy and that this superiority could stem from the perceptual and cognitive skills possessed by the skilled performers. The use of action-outcome sequences as a source of situational probability has also been addressed with similar results in tennis (Triolet *et al.*, 2013; Murphy *et al.*, 2016) as well as baseball (Gray, 2002).

It is important to note that the overreliance on sequence information could be detrimental to skilled performance. Loffing and colleagues investigated volleyball players' bias of visual anticipation of action-outcome in subsequent trials based on previous action-outcomes. Volleyball players were required to predict the type of an opponent's attack after watching a temporally occluded video by pressing buttons on a computer keyboard. It was found that participants tended to preferentially expect the continuation of an action-outcome pattern, while possibly attaching less importance to kinematic cues, meaning that an overreliance on the continuation of a pattern can be detrimental to anticipation in situations where the action-outcome does not correspond to the pattern. More specifically, it was found that when the outcome of a target trial was congruent with the preceding pattern of attack, the prediction accuracy was higher and response time was lower compared to incongruent trials (Loffing *et al.*, 2015). Similarly, Canãl-Bruland, Filius & Oudejans (2015) showed that when baseball batters preferentially expected the continuation of an action-outcome, they failed to adjust their movement initiation patterns accordingly. Therefore, in highly time-constrained situations, one's expectations (e.g., informed by sequences of action-outcomes) can impact perception as well as motor responses (Loffing & Cañal-Bruland, 2017).

2.4.2.1.4. Tactical Dominance

Another source of situational probability information may stem from the intentions of the opponent based on tactical initiative. Crognier and Fery (2005) aimed to demonstrate that the main source of information that tennis players use to anticipate their opponents' strokes is prior knowledge of upcoming events likely to develop when the player has the opportunity to impose his or her playing intent. Seventeen skilled male tennis players were faced with simulated on-court situations with three different delivery conditions such that their tactical initiative was high, moderate or weak (reflecting the possibilities of controlling rallies). For example, in tennis, the player in the volley position may fake an interceptive movement towards one side of the court to induce the opponent to make a stroke towards the other side, which is then easily anticipated. Similarly, by using a certain positional stance in which to return a serve, the player may force his or her opponent to serve in the expected direction. The results indicated that when they had tactical control of the rallies, skilled tennis players could accurately (approximately 80%) predict the direction of shots. In contrast, the accuracy of directional responses was considerably lower in situations of lower tactical dominance. The authors concluded that the kinematic information extracted from the stroke of the opponent must be advantageously complemented by tactical information which precedes the stroke.

Furthermore, 'naturalistic decision making' research in the sporting domain has revealed the importance of match-specific contextual factors (Levi & Jackson, 2018). One such study indicated that skilled badminton players only attempted to finish a point when situational conditions of the rally were perceived to be favourable to winning the point. The players expressed that their intentions and decisions reflected the contextual development of a rally and that past events and current player competencies were used to inform their situational understanding (Macquet & Fleurance, 2007).

2.4.2.2. Situational Probability and Expertise

The differences between levels of expertise have shown to be an area of interest in the field of situational probabilities. For example, Murphy and colleagues investigated whether situational probability information could facilitate anticipation independent of postural information. In this study, skilled and less-skilled tennis players viewed video footage of rallies from real tennis matches as well as animations of the same rallies in which each of the players were replaced by a cylinder and their rackets were not visible. These videos were occluded, and the tennis players were required to verbally indicate the depth and direction of the ball bounce location while swinging the racket and moving as though they would when returning the shot. Although both groups anticipated more accurately when viewing the actual video compared to the animated film, the skilled group anticipated significantly better than the less-skilled groups when viewing the animations. This means that skilled performers can rely solely on contextual information to anticipate successfully. The authors suggested that skilled performers are able to access task-relevant information from LTM to facilitate more accurate information when compared to less-skilled participants (Murphy *et al.*, 2016). This ability of skilled performers to make effective use of situational probability information has been built on similar research in baseball (Gray, 2002) and tennis (Shim *et al.*, 2005).

Researchers have studied the use of situational probability for anticipation by providing explicit (See Mann *et al.*, 2014) as well as implicit information. Farrow and Reid (2012) identified the game score in tennis as one source that may provide implicit situational probability information and thereby facilitate anticipation. Participants were asked to predict the location of serves presented on a video as soon as they felt as though they knew the location. The game score was manipulated in such a way that provided advance probability information about the shot direction of the first service of each game. The results indicated that skilled, but not less-skilled performers picked up on and made use of the information conveyed by the game score. These performers also initiated their responses earlier (before the movement action of the opposition had been carried out). This suggests that these performers were using the probability information to inform their response as no kinematic information from the service had been presented. The study in karate by Milazzo *et al.* (2016) extend these findings as skilled, but not less-skilled karate fighters were able to implicitly pick up the attack pattern of the opponent after the fifth repetition. Similarly in the study by Runswick *et al.* (2018a) skilled cricket batsmen were able to use the game situation to inform their anticipation.

Taken together, these studies suggest that skilled performers benefit from a prior knowledge base of probable upcoming events (Crognier & Féry, 2005), and are able to identify situational probabilities without explicit information provided. Throughout the process of recognizing situational probability information, the extraction of knowledge appears to orientate the skilled performer's attention to relevant information (Henderson, 2003).

The amount of previous accumulative exposure to an opponent has also been investigated in terms of expertise differences and situational probability. For example, McRobert *et al*. (2011) manipulated contextual information to examine the perceptual-cognitive process that supported information using a simulated cricket-batting task. In their study, skilled and less-skilled cricket batters responded via pen and paper to video simulations opponents bowling a cricket ball under high (viewing their opponent multiple times) and low (responding to an opponent without previously seeing them bowl) contextual information conditions. The test procedure made use of an eye-tracker and a microphone in order to capture visual search and verbal report data respectively. The study found that skilled batters were more accurate in their responses during the high-context conditions compared to the less-skilled batters. This suggests that the additional context allowed performers to extract information from the relevant locations more effectively. Moreover, the extra information available in the high-context condition resulted in the mean fixation duration employed by skilled batters as they were able to extract information from the relevant location more efficiently. More recently, it was also reported that skilled cricketers could make more accurate judgements based solely on the context available prior to any kinematic information, and that kinematic cues were only considered to be important for anticipation in the final moments of the bowling sequence (Runswick, Roca, Williams, McRobert & North, 2018b).

In summary, these findings emphasize the importance of both kinematic and situational probability information for as perceptual-cognitive skills needed for anticipation; and that in the absence of kinematic information, perceptual-cognitive expertise is underpinned by processes that facilitate the effective processing of situational probability information.

2.4.3. Integration of Perceptual-Cognitive skills

While the importance of kinematic cues and situational probability information has been established, it is likely that successful anticipation is dependent on the integration of both of these perceptual-cognitive skills. An important perceptual-cognitive skill that has been identified as a key component of anticipation is the ability to prioritize the importance of events unfolding in the environment (Williams & Jackson, 2019). It has been highlighted that skilled performers are more accurate in their predictions of what will happen next; are better at identifying task-relevant options, while ignoring irrelevant ones; and are more accurate in rank ordering those options. It is assumed that the skilled performer’s more accurate mental representations of the potential alternative courses of action that an opponent might take are positively associated with superior anticipation. Farrow and colleagues suggested that it is likely that an assortment of domain-specific task constraints all provides information to a skilled performer when completing an anticipatory skill. These may include extraction of opposition's kinematic information; assignment of situational probabilities based on previous experiences; and the recognition of specific patterns of play (Farrow *et al.*, 2010).

Several attempts have been made to examine how the relevant importance of each of these sources varies across different domain-specific tasks and situations. For example, Roca and colleagues examined how perceptual-cognitive skills such as kinematic cues, pattern recognition, and situational probabilities interact during the performance in a task that was representative and dynamic. In this study, skilled and less-skilled soccer players interacted with soccer sequences filmed from the perspective of a central defender under two different task constraints in which the ball was located in the attacking (far condition) or defensive (near condition) side of the pitch. Soccer players' eye movement and retrospective verbal reports of thinking were recorded during both conditions. In the far task, skilled participants made more statements related to the relational information between the players (i.e., pattern recognition), while in the near condition, players verbalized more thought processes related to the postural orientation (i.e., kinematic cues) of players or what their opponents were likely to do in the given scenario (i.e., situational probabilities) (Roca, Ford, McRobert & Williams, 2013).

Additionally, the nature and frequency of anticipation and how spatiotemporal constraints affect these behaviours has also been examined by Triolet *et al*. (2013). It was proposed that early anticipation occurs when players are able to use significant context-specific information before the opponent's stroke in tennis. However, when such information is not available, anticipation happens closer to the moment of ball-racket impact. This suggests that the information used is more likely to be based on the postural cues of the opponent in preparation of the stroke. Furthermore, Runswick *et al*. (2018a) reported that when 80ms of ball flight information was available to skilled cricket batters, the prioritization of information switched from contextual information to that arising from the kinematics of the bowler and ball flight. Therefore, it is possible that skilled batters would be able to use kinematic and ball flight information to correct responses from the use of a context that was incongruent. Additionally, Cork *et al.* (2010) suggested that information regarding an individual delivery arising from the anatomical positions and movement of the bowler's body is added to existing knowledge that the batsman has regarding the style and pace with which the bowler bowls.

Furthermore, probability information in combination with advance kinematic information is essential for skilled performance as it assists the performer in making a more informed critical decision, such as to which side of a court to move to play the return stroke in sports such as squash or tennis; or whether to shift weight onto the front foot or back foot to strike a ball in cricket. Such early information is sufficient to facilitate the performer to move toward the global destination for the next stroke (in racket sports) or to guide the action when swinging at a ball (in sports such as cricket and baseball). Once this global information is used, much later occurring and more precise information (such as ball flight) is used to fine-tune the motor response. Hence, the prediction of flight direction is refined by a progressive alternation from situational probability information to more localized kinematic information (Müller & Abernethy, 2012).

Relating to constraints of the task, it is likely that the ability to identify familiarity of stimuli in patterns of play is crucial in team ball games including soccer, hockey, rugby, and basketball. In contrast, in racket sports such as tennis, squash, and badminton, the information utilized from an opponent's postural orientation may be more important than the ability to identify patterns of play. It is possible that in certain situations, performers may rely exclusively on an opponent's postural orientation to process information, while others may make anticipatory judgements using situational probability alone (Williams, 2009). Provided the temporal variations in the availability of different sources of information, it can be assumed that in anticipatory decision-making, depending on the current stage of an opponent's action, information emanating from contextual and kinematic cues is weighted differently. More specifically, at early stages of decision-making, performers' expectations of an action-outcome should rely predominantly on contextual information during conditions of uncertainty (Körding, 2007), and then be modified based on the sensory input perceived during the unfolding action's kinematics (Loffing & Hagemann, 2014b).

Ultimately, probability and/or kinematic information is sufficient to give the skilled performer an idea of the appropriate "ball-park" location to which to move to execute a return shot or make successful bat-ball contact. For less-skilled performers, later (ball flight) information is needed to arrive at comparable levels of "ball-park" specification (Müller & Abernethy, 2012; Murphy *et al.*, 2018). When access to tactical information is limited or when no probabilistic tendencies can be extracted, performers wait longer and potentially make anticipation responses based on information arising from the postural orientation of the opponent immediately before ball release or ball-racket contact (Triolet *et al.*, 2013).

Collectively, contextual information in combinations with opposition kinematics seems necessary for action-outcome anticipation (Loffing & Hagemann, 2014b). The integration of tactical contextual information allows performers to build a specific model of their opponent based on meaningful contextual information from previous competitions as well as the current situation as it progresses (McRobert *et al.*, 2011). The studies discussed in this section, however, have failed to identify exactly which sources of contextual information are potentially integrated into skilled performers' anticipatory decisions. For example, it is unclear whether skilled performers relied on the opposition or their own on-court position, their knowledge about opponents' strengths or weaknesses, or about their action preferences, which are all potential components of contextual information (Loffing & Hagemann, 2014b).

Chapter 3: Research Methods and Procedures

3.1. Introduction

In order to achieve the aim of this study, it is important to apply the appropriate research methods and procedures. Therefore, an in-situ cricket batting task was used to collect data from skilled batsmen in Nelson Mandela Bay. This chapter outlines the relevant methods used in order to carry out the investigation; to facilitate repeatability of the study, and to interpret the results. The chapter commences with details surrounding the research design that was chosen to conduct the study, as well as the measuring instruments and the data collecting procedure. Details pertaining to the analysis of data and ethical considerations complete this chapter.

3.2. Research Design

A quantitative quasi-experimental research design was employed for the purpose of this study as a single group of participants was observed after being presented with information (situational probability information) presumed to cause change (Wang, Morgan & Salkind, 2012). A one-group post-test-only, within-participant design with multiple conditions (including a control condition) was used as this study investigated a single instance that was implicitly compared with other events casually observed and remembered. Furthermore, each participant was exposed to every condition.(De Vos, Strydom, Fouche & Delport, 2005). In this study, only one group of cricket players was tested on a single occasion regarding the variables of interest such as prediction accuracy, response accuracy and initial movement times.

3.3. Participants and Sampling Technique

Skilled cricket batsmen (n=15) from the top five cricket clubs (ranked according to the previous season's log) in Nelson Mandela Bay were used for this study. According to a study by Weissensteiner and colleagues, cricket batsmen do not make use of anticipation until the age of 17 (Weissensteiner, Abernerthy, Farow and Muller, 2008), therefore players below this age were excluded from participation in this study. This indicates that senior cricket batsmen were suitable for this study. Therefore, participants who took part in this study had an average age of 21.73 ± 2.81 years and had an average of 16.00 ± 3.14 years of cricket playing experience. Nine of the participants had previous experience playing at age group or senior provincial level, while the remaining six participants played at a senior club level in Nelson Mandela Bay.

The sample relevant for this study was required to meet the following inclusion criteria:

- Be a male;
- Be a member of one of the top five senior cricket clubs in Nelson Mandela Bay;
- Be in the top six batsmen of the club, ranked according to team batting order;
- Be able to attend the required testing day;
- Be injury-free;
- Be over the age of 18 years old

This study made use of purposive and convenience sampling methods. Purposive involves selecting specific individuals based on an explicit purpose rather than random selection (Teddlie & Yu, 2007). The investigation of batsmen's use of different sources of situational probability is specific to the game of cricket and a level of expertise. For this reason, participants were purposefully selected according to the inclusion criteria as specific characteristics of the participants (cricket batsmen) were required. Convenience sampling was used as the participants were from Nelson Mandela Bay.

3.4. Pilot Testing

Within this study, two sessions of pilot testing took place. The first session was used to evaluate which speed setting of the bowling machine produced the desired ball projection velocities. A video camera (GoPro Hero 5 Black, China) recording at 100 frames per second was positioned to the side of an outdoor cricket pitch in such a way that it could capture both the release point of the bowling machine and the rest of the length of the pitch.

Consistent with Müller *et al.* (2009), ball velocity was calculated using the following formula:
Velocity (m/s) = distance (m)/time (s).

The distance was 17.68m from the exit of the bowling machine to the participant's probable stance position. Travel time of the ball was calculated through a frame by frame analysis and converted to seconds. This technique was used at a number of different speed settings on the bowling machine in order to determine which speed setting produced a ball velocity of between 100 and 120km/hour which equates to medium pace bowling (Cricvision, 2019), consistent with (Müller *et al.*, 2009). A bowling velocity higher than this was not considered in order to maintain safety of the participants.

The second session of pilot testing was used in order to familiarise the researcher and research assistant with the testing procedure; to check the functioning of all equipment used, and to become aware of how long each testing session would take with the participants. The entire testing procedure was conducted with a volunteer who matched the inclusion criteria for this study. The data collected from this testing were not included in the final results.

3.5. Testing Setup

Prior to each participant arriving, the testing facility was prepared in the following manner in order to carry out the testing procedure:

A 220-volt Jugs Cricket Bowling Machine was set up at the popping crease on an outdoor natural cricket pitch (which was rolled and prepared before every testing session) in such a way that it simulated a right arm bowler bowling over the wicket (just to the right of the wicket when viewed from the batsman's perspective). The bowling machine was set up on the North end of a pitch running from North to South. This ensured that the sun would not be behind the bowling machine regardless of what time testing took place. The participant was positioned on the opposite side of the pitch at a distance of 17.68m away from the bowling machine (See Figure 3.1). The bowling machine was used as opposed to actual opponents (or bowlers) in order to maintain consistency in delivery type as well as to eliminate the use of kinematic cues for anticipating the type of delivery bowled. In order to ensure that the ball pitched in the correct position, a laser pointer (500 mw HY 303 laser pointer) was mounted to the bowling machine and set up that when shining, it aligned with where the ball would pitch. This ensured that situational probabilities (action preferences and field placements) were the sole sources of advanced information that the participants could use for predicting delivery type.

The bowling machine was set up at a release height of 2.1m in order to simulate the average release height of a fast bowler in cricket, which has found to be between 1.91 and 2.27m (Worthington, 2010). In order to mask the positioning of the release point of the ball machine, a screen was placed in front of the machine (Refer to Figure 3.2). This ensured that participants were not able to use the positioning of the bowling machine to predict the line and length of the delivery. A small opening in the screen was aligned with the release point of the ball machine to allow each ball to be delivered to the participants. Each delivery was projected at a velocity between 100 and 120 km/hr, and a dimpled Kookaburra bowling machine ball was used in order to negate the effects of swing and seam movement that would occur with a regular cricket ball. This was important in order to minimize the effect that swing and seam movement may have had on response accuracy and initial movement time of the participant.

Finally, a video camera (GoPro Hero 5 Black, China) recording at 100 frames per second was positioned on the field in such a way that it could capture both the release point of the bowling machine and the participant moving in response to the ball released from the bowling machine in order to determine initial movement time of the participants (Refer to Figure 3.1).

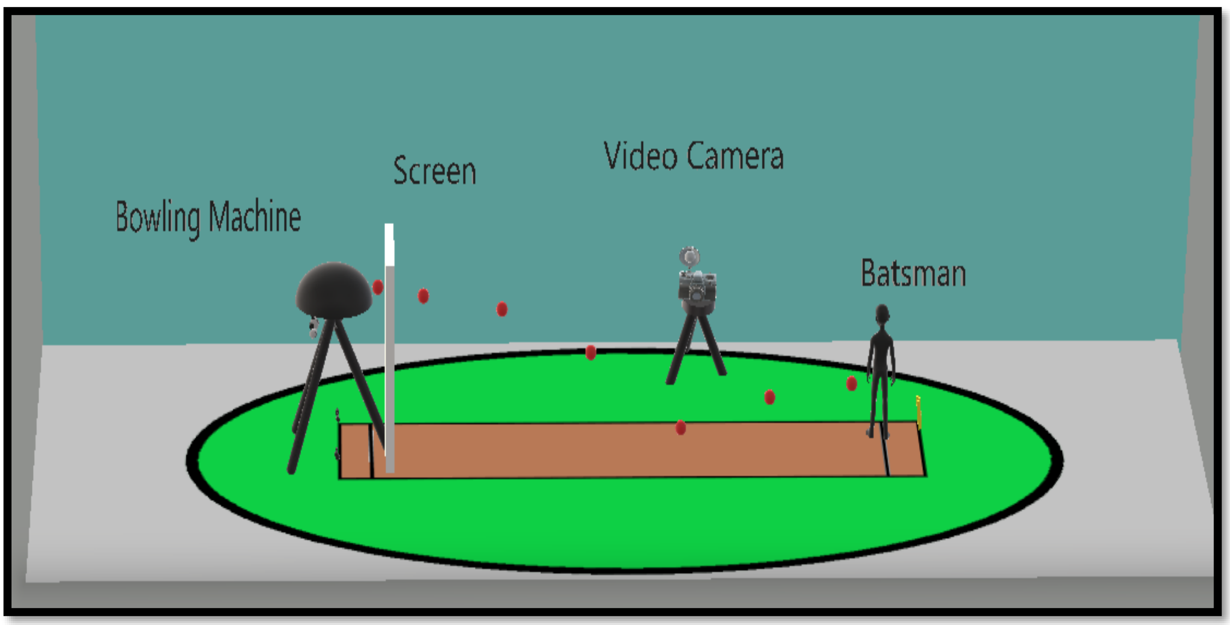

Figure 3.1- Setup of the testing procedure

Figure 3.2- Setup of bowling machine from the participant's point of view

In order to investigate the sources of situational probability used by skilled cricket batsmen, an in-situ test was performed. In this test, skilled cricket batsmen were required to face 12 overs (72 deliveries) bowled by a bowling machine and predict the landing position (delivery outcome) of each delivery through the use of a verbal response. Participants were then encouraged to play an attacking shot for each delivery in an attempt to make successful bat-ball contact. At the start of each trial, the ball was held up in the air by the research assistant feeding the bowling machine so that the batsmen could clearly see the ball and would be aware that the trial was about to commence. The ball was then placed into the bowling machine after a period deemed appropriate by the research assistant. Participants undertook testing sessions independent of each other.

In order to be able to predict the type of delivery to be bowled, the participants had two different sources of situational probability available. These sources included the use of field placement as well as action preferences of the opponent. These sources of situational probability were used in isolation as well as in combination to describe four different conditions:

1. Control trials (No sources)
2. Field placement alone
3. Action preference alone
4. Field placement and action preference (Both sources)

The bowling machine represented two different ‘opponents’ bowling alternating overs (groups of six deliveries). In overs bowled by ‘opponent one’, the only source of situational probability available was the placement of the fielders, while some deliveries contained no sources of situational probability. In overs bowled by ‘opponent two’, sources of situational probability available included action preference alone as well as both sources.

Possible types of deliveries that were bowled included a ‘Short, Legside’ delivery (a delivery which is pitched shorter, and on the legside of the batsman) as well as other deliveries which were directed to bounce in other areas of the pitch, as seen in the pitch map in Appendix 3. While ‘opponent one’ bowled an equal distribution of ‘Short, Legside’ and random deliveries, ‘opponent two’ bowled ‘Short, Legside’ deliveries for 67% of all trials. Opponents one and two bowled ‘Short, Legside’ deliveries when the conditions of situational probability were either congruent or incongruent with a ‘Short, Legside’ delivery. Before each delivery, a diagram of the field placements set for the upcoming delivery (set by three level-3 qualified cricket coaches) was shown to the participant in order to assist them in making their predictions. One of the field-placement diagrams was tactically set to suggest the delivery of a ‘Short, Legside’ delivery, while the other three diagrams were randomly set in order to give no indication of the event outcome of the following delivery (See Appendix 4). These diagrams were adapted for left-handed batsmen.

A realistic hypothetical game situation was created using the congruency of the outcome of each delivery and the condition of situational probability available. In cricket, the congruency of the event outcome can be determined by two factors: whether the bowler intends to deceive the batsman through the use of game tactics; or whether the bowler executes the delivery as intended. For this reason, each condition consisted of one or more categories of congruency:

1. A congruent trial was one where the type of delivery bowled (i.e., event outcome) was tactically appropriate to the conditions of situational probability available.
2. An incongruent trial was one where the type of delivery bowled (i.e., event outcome) was not tactically appropriate to the conditions of situational probability available.

3. A trial of no congruency was a trial in which no sources of situational probability were available, therefore the delivery could not be congruent or incongruent to the condition. In these trials, the field placements presented to batsmen were random and did not provide any indication of the event outcome of the following delivery. These were the control trials.

Together, the conditions of situational probability and categories of congruency formed seven different combinations:

- Control trials (No sources)
- Field placement alone- Congruent
- Field placement alone- Incongruent
- Action preference alone- Congruent
- Action preference alone- Incongruent
- Both sources- Congruent
- Both sources- Incongruent

Two different variations of the order of trials were used in order to ensure that participants did not communicate the order of trials with each other. An example of the sequence of deliveries is shown in Appendix 2. The type of delivery, as well as the field placements, were distributed according to Table 3.1 and Table 3.2 below. The trials were created in such a way that there were equal trial numbers of each type of condition.

Table 3.1- Distribution of all trials according to the condition of situational probability available

Action Preference	Not Present		Present	
Field Placement	Random	Short, Legside	Random	Short, Legside
Condition	Control trials	Field placement alone	Action preference alone	Both sources
Number of trials	18	18	18	18
Total Trials	36		36	

Table 3.2- Distribution of all trials according to the opponent, condition of situational probability as well as the category of congruency

Opponent	Action Preference	Condition	Congruency	Combination	Field Placement	Actual Delivery	Number of deliveries
1	No	Control trials (No Sources)	No Congruency	A	Random	Random	18
		Field placement Alone	Congruent	1	Short, Legside	Short, Legside	9
			Incongruent	2	Short, Legside	Random	9
2	Yes	Action Preference Alone	Incongruent	3	Random	Random	6
			Congruent	4	Random	Short, Legside	12
		Both Sources	Congruent	5	Short, Legside	Short, Legside	12
			Incongruent	6	Short, Legside	Random	6

3.6. Measuring Instruments

For the purpose of this study, the following variables were measured to collect the data for analysis:

3.6.1. Prediction Accuracy

At the start of every trial, participants were required to answer a few questions relating to the next delivery, using situational probability information provided by the researcher. The participants responded by verbally answering the questions and the researcher recorded the answers on a data collection sheet (see Appendix 5).

The researcher asked the participant the following questions:

a) “What line do you expect the following delivery to be?”

The following options were provided to answer this question:

a) Offside
b) Legside

b) "What length do you expect the following delivery to be?"

The following options were provided to answer this question:

a) Short
b) Full

A successful trial in terms of prediction accuracy was one where both delivery line and length were predicted correctly by the participant. Therefore, since a participant's complete delivery outcome prediction was one of four possible options (Short, Legside; Short, Offside; Full, Legside; Full, Offside), chance level for prediction accuracy was 25%.

c) How certain are you that your predictions are correct?

The following Likert scale was used by participants to indicate their level of certainty:

1- Not at all certain
2- Slightly certain
3- Somewhat certain
4- Moderately certain
5- Extremely certain

A high certainty level indicates subjective awareness of the information used to make judgements (Murphy *et al.*, 2018).

d) "What information did you use to make this prediction?"

This question was in the form of a verbal report. Responses to this question were divided into four categories by the researcher:

- Field placement information
- Action preference information
- Both sources of information
- Other information (e.g., previous delivery type)

These questions were asked after participants were shown a diagram of the field placements for the upcoming delivery and bowling machine was set up.

3.6.2. Response Accuracy

After each ball was delivered, the participants were required to strike the ball. Points were awarded as follows:

0 points: Unsuccessful trial- No bat-ball contact; or bat-ball contact made, but the ball did not travel in the intended direction. Since the participants were encouraged to play in an attacking manner, if no attempt was made to hit the ball, it was considered an unsuccessful trial.

1 point: Successful trial- Bat-ball contact made, and the ball did travel in the intended direction.

The researcher and research assistant, with adequate knowledge of cricket batting, determined whether each trial was successful or unsuccessful in terms of response accuracy. Furthermore, each trial was digitally recorded with a video camera and the footage was reviewed in order to confirm the response accuracy of the participants recorded by the researcher.

3.6.3. Initial Movement Time

For each ball that was delivered, the participant's initial movement time was determined. To do this, a video camera (GoPro Hero 5 Black, China) recorded each delivery at 100 frames per second (i.e., one frame missed accounted for 0.01s of footage), and the footage was analysed in order to determine initial movement time. The point of reference was defined as the moment at which the ball exited the bowling machine. Initial movement time was determined by the difference in time between the participant's first preparatory foot movements and the ball exiting the bowling machine.

Initial movements made by the participants prior to ball release were considered as a negative movement time, while preparatory movements made by the participants after ball release were considered as a positive movement time. Initial movement time could be used to corroborate prediction accuracy obtained from the verbal response. Coding of these videos was performed by the researcher who had adequate knowledge of cricket batting. Trigger movements (routine preparatory movements made by the batsman significantly prior to ball release) were not considered when determining initial movement time. The researcher determined whether the participant made use of a trigger movement.

3.7. Data Collection and Testing Procedure

On testing days, participants arrived at the testing venue and completed an informed consent form (refer to Appendix 6). The testing procedure was then explained to the participant by the researcher. Thereafter, the participant was instructed on how to give a verbal response as this requires an unconscious task to become more cognitive in nature. Participants then equipped themselves with the necessary protective gear before facing a total of 20 familiarization trials in order to practice completing the verbal response and to familiarize themselves with the speed of the bowling machine. After completion of the familiarization trials, the participants were explicitly informed that opponent one does not possess an action preference, and that opponent two has an action preference (67% of all deliveries bowled by opponent two will be “Short, Legside” deliveries, pitching short on the legside).

Before each ball was delivered from the bowling machine, the researcher recorded the participant’s verbal response for prediction accuracy, while after each delivery, the participant’s response accuracy was recorded. Explicit feedback of prediction accuracy was not provided to participants, but after facing each delivery, participants were aware of their prediction accuracy. For each ball that was delivered, the participant’s initial movement time was also recorded using the video camera, but coded frame by frame post data collection. After every two overs, (approximately every ten minutes), the researcher and research assistant collected balls previously projected from the bowling machine. During this time, the participants were able to have a break in order to drink water and mentally refocus for the subsequent trials. Upon completion of the testing procedure, a debrief was performed by the researcher in which the researcher thanked the batsmen for their participation.

3.8. Data Coding

Coding of data was required in order to determine the initial movement time for each delivery. The initial step of the coding process was to download the video footage of each participant from the video camera used. These videos were then uploaded onto Dartfish video analysis software (Dartfish Video Solution Version 9.0.)

The second step of this process was to analyse each video clip frame by frame (100 frames per second) using Dartfish Video Solution Version 9.0. to determine the time at which the ball exited the bowling machine and the time of the participant's first preparatory foot movements (See Figure 3.3). The researcher conducted this coding and is a certified Dartfish technologist. The difference in time between these two events was considered the initial movement time of the participant. It is worth noting that Dartfish has the ability to zoom in order to provide a clear image of the participant's foot movements.

Figure 3.3- Frame by frame analysis depicting zoomed images of the participant and exit point of the bowling machine

3.9. Analysis of Data

A qualified statistician was enlisted to assist with the analysis of the data collected. Prediction accuracy and response accuracy statistics were run according to overall participant data, while initial movement time statistics were run according to all valid trials. Descriptive statistics such as the mean, standard deviation, median, minimum, maximum and quartiles were used to describe prediction accuracy, response accuracy and initial movement times. Graphical representations such as bar graphs were used to depict these results, which will also report a 95% confidence interval. Frequency distribution graphs were used to depict the distribution of the level of certainty associated with prediction accuracy as well as the sources used by batsmen to inform their predictions of the delivery outcome acquired through the verbal report. Chance level was set at 25% for prediction accuracy as there were four possible options when making a prediction of the forthcoming delivery; and 50% for response accuracy. A one-sample t-test was used in order to test for significant differences between chance level and prediction and response accuracies, and Cohen's *d* values were used to indicate practical significance. The size of the practical significance was classified as follows:

- Small: $0.2 \leq d < 0.5$
- Moderate: $0.5 \leq d < 0.8$
- Large: $d \geq 0.8$

Parametric inferential statistics were employed in order to test the statistically significant differences within categories of congruency; conditions of situational probability; as well as combinations of congruencies and conditions. The alpha level was set at 0.05 for the purpose of identifying statistical significance. Partial eta squared statistics were used to determine the practical significance of the mean prediction and response accuracy differences between congruencies, conditions and combinations. These were only reported when the means showed statistically significant differences. The size of the practical significance was classified as follows:

- Small: $\eta_p^2 < 0.09$
- Moderate: $0.09 \leq \eta_p^2 < 0.25$
- Large: $\eta_p^2 \geq 0.25$

One-way analysis of variance (ANOVA) was used to compare control trials to all other combinations for prediction accuracy, response accuracy and initial movement time. This was followed by a Dunnett post-hoc test in order to identify where statistically significant differences were present. One-way analysis of variance was also employed in order to compare the different conditions of situational probabilities to each other; and categories of congruency to each other for prediction accuracy and response accuracy. A Tukey honestly significant difference (HSD) test was used to determine where statistically significant differences were present. In order to test for the interaction of condition and congruency for prediction and response accuracy as well as initial movement time, a two-way analysis of variance was used. This two-way ANOVA did not include control trials as these could not be split between congruent and incongruent trials. A Tukey HSD test was again used in order to identify where significant differences were present.

3.10. Consideration of Ethics

Permission to conduct this study was sought from the Nelson Mandela University Faculty Postgraduate Studies Committee (FPGSC) and Research Ethics Committee (Human). The reference number allocated to the study is H18-HEA-HMS-004. As per the criteria pertaining to participants, only participants who were injury-free were selected to take part in the testing procedure. Safety measures were considered in the event a participant sustained and injury. This included having a Health and Safety officer present at the facilities on the days of testing. In order to protect the participants in this study, they were required to wear protective batting gear including a helmet as per the standard requirements of the game of cricket. All participation in this study was voluntary and all participants completed informed consent forms prior to their participation in the study. The researcher ensured all the participants understood the requirements to be fulfilled even after informed consent was provided.

The chapter to follow will discuss the results obtained, ultimately to attain the aims and objectives of the current study.

Chapter 4: Results

4.1. Introduction

Chapter 4 depicts the results obtained from the research conducted. It includes the descriptive and inferential statistics for prediction and response accuracies according to conditions and congruencies. Post-hoc tests were also conducted in order to identify where differences were found between conditions of situational probability as well as categories of congruency. This chapter also includes results from the research related to batsmen's certainties of their prediction as well as the sources of information used to inform these predictions. Following the results of response accuracy, this chapter culminates with descriptive and inferential statistics surrounding initial movement times of batsmen when attempting to strike each delivery. Note that descriptive results are reported in-text as the mean (M) ± standard deviation.

4.2. Prediction Accuracy

This section provides details of results obtained regarding the prediction accuracy of batsmen.

Table 4.1- Descriptive statistics for overall prediction accuracy (%) of batsmen when anticipating the following delivery.

	Overall
Number of participants	15
Mean	43.61
Standard deviation	3.59
Minimum	37.50
Quartile 1	41.67
Median	43.06
Quartile 3	46.53
Maximum	50.00

The prediction accuracy of batsmen for all trials was 43.61 ± 3.59%. The minimum prediction accuracy of batsmen was 37.50% while the maximum was 50.00%, resulting in a range of 12.50% (See Table 4.1). It is interesting to note that a one-sample t-test revealed that the mean overall prediction accuracy of batsmen was significantly higher than chance level ($t(14) = 20.08$, $p < 0.001$, $d = 5.18$).

Table 4.2- Descriptive statistics regarding prediction accuracy (%) of batsmen when anticipating the following delivery for each condition of situational probability, regardless of congruency.

	Control trials	Field placement alone	Action preference alone	Both sources
Number of participants	15	15	15	15
Mean	26.67	52.96	41.11	53.70
Standard deviation	9.89	10.68	15.83	10.43
Minimum	11.11	38.89	11.11	33.33
Quartile 1	22.22	44.44	33.33	47.22
Median	22.22	50.00	38.89	55.56
Quartile 3	30.56	55.56	58.33	61.11
Maximum	44.44	72.22	61.11	66.67

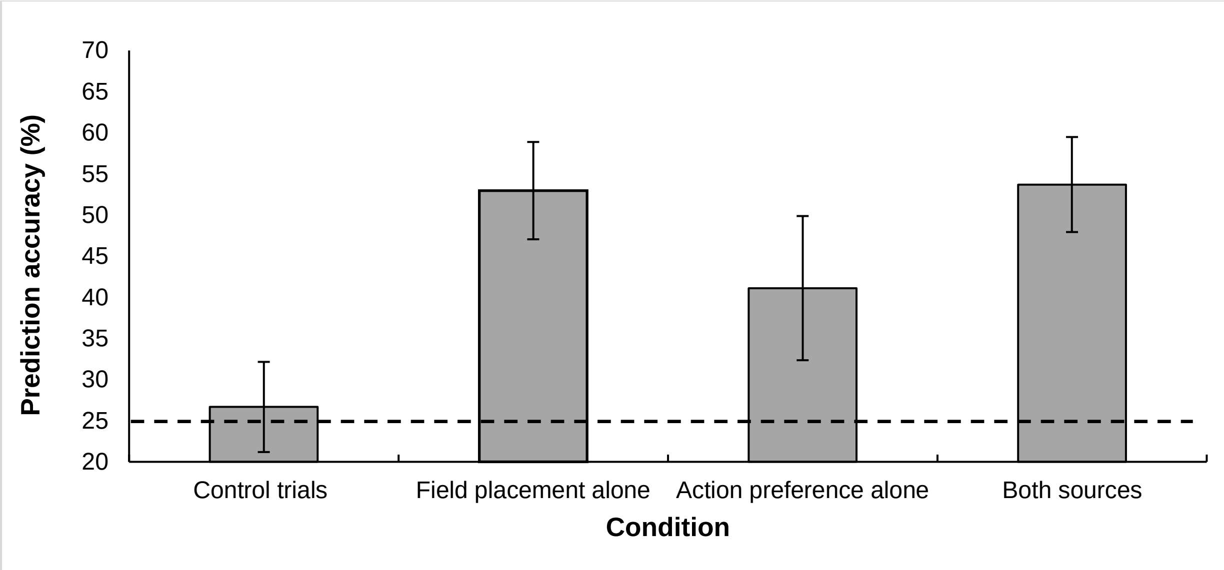

Figure 4.1- Bar graph indicating prediction accuracy (%) of batsmen when anticipating the following delivery for each condition of situational probability, regardless of congruency. Error bars indicate 95% confidence intervals. The dotted line represents chance level (25%) for prediction accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and prediction accuracies for each condition. When either one source (field placement alone: ($t(14)=10.14$, $p<0.001$, $d=2.62$); action preferences alone: ($t(14)=3.94$, $p=0.001$, $d=1.02$)) or both sources ($t(14)=10.66$, $p<0.001$, $d=2.75$) of situational probability were available, prediction accuracy was substantially greater than chance level. When no sources were available however, prediction accuracy of batsmen was not significantly different to chance level ($t(14)=0.65$, $p=0.524$).

A one-way ANOVA was used to compare batsmen's prediction accuracy for conditions of situational probability, regardless of congruency. Significant differences were found for prediction accuracy between conditions of situational probability available, regardless of congruency ($F(3,56)=16.90$, $p<0.001$, $\eta_p^2=.48$). A Tukey HSD test was used to determine where statistically significant differences were present for prediction accuracy between the conditions of situational probability.

Post-hoc tests revealed that batsmen were significantly less accurate when predicting control trials (M=26.67 ± 9.89%) compared to conditions of field placement alone (p<0.001); action preferences alone (p=0.008) and both sources (p<0.001). Additionally, trials containing action preferences alone resulted in lower prediction accuracies than trials with field placement information alone (p=0.042) and when both sources of situational probability were available (p=0.028). However, there was no significant difference in prediction accuracies of batsmen between conditions of field placement alone and both sources (p=0.998).

Table 4.3- Descriptive statistics for prediction accuracy (%) of batsmen when anticipating the following delivery for control trials, as well as each category of congruency, regardless of condition.

	Control trials	Congruent trials	Incongruent trials
Number of participants	15	15	15
Mean	26.67	62.42	28.57
Standard deviation	9.89	8.86	11.09
Minimum	11.11	45.45	4.76
Quartile 1	22.22	57.58	21.43
Median	22.22	60.61	28.57
Quartile 3	30.56	68.18	35.71
Maximum	44.44	81.82	42.86

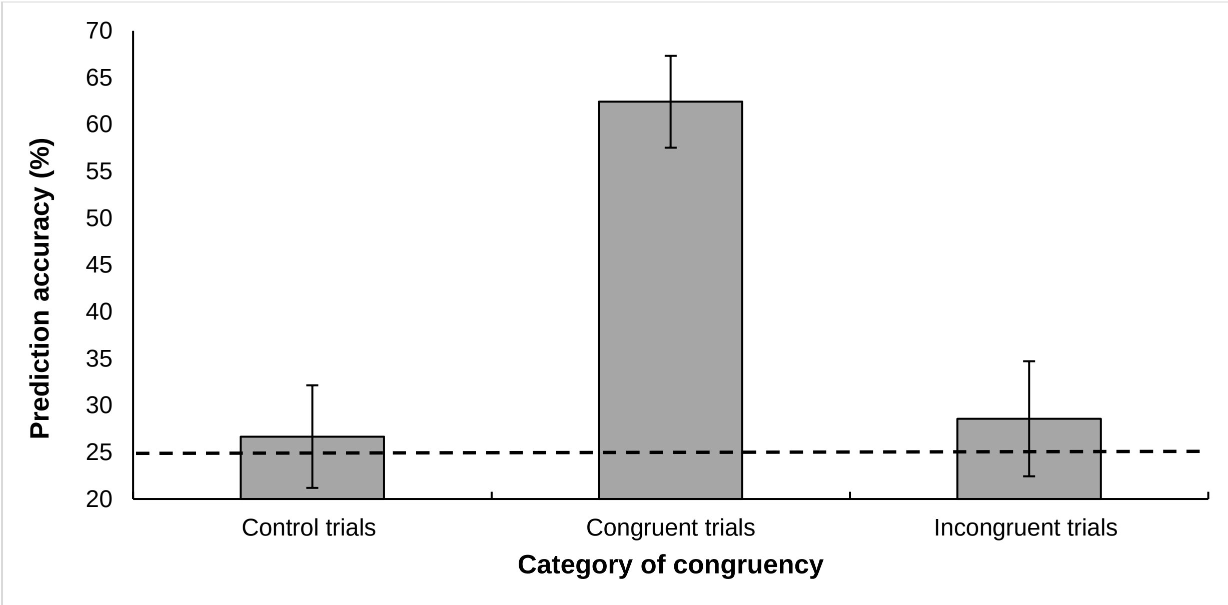

Figure 4.2- Bar graph indicating prediction accuracy (%) of batsmen when anticipating the following delivery for control trials, as well as each category of congruency, regardless of condition. Error bars indicate 95% confidence interval. The dotted line represents chance level (25%) for prediction accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and prediction accuracies for each category of congruency. It is interesting to note that batsmen's prediction accuracy for incongruent trials was not significantly different to chance level ($t(14)=1.25$, $p=0.233$), however this was not the case for congruent trials ($t(14)=16.36$, $p<0.001$, $d=4.22$).

A one-way ANOVA was used to compare batsmen's prediction accuracy for congruency, regardless of conditions of situational probability. Significant differences were found for prediction accuracy between categories of congruency, regardless of conditions of situational probability available ($F(2,102)=34.04$, $p<0.001$, $\eta_p^2= .40$). A Tukey HSD test was used to determine where statistically significant differences were present for prediction accuracy between the categories of congruency. Post-hoc tests revealed that batsmen were significantly more accurate when predicting the delivery outcome of the congruent trials (M=62.42 ± 8.86%) than incongruent trials ($p<0.001$) and control trials ($p<0.001$) (See Table 4.3 and Figure 4.2).

Table 4.4- Descriptive statistics regarding prediction accuracy (%) of batsmen when anticipating the following delivery for control trials as well as congruent and incongruent trials of each condition of situational probability

	Control trials	Field placement alone		Action preference alone		Both sources	
Congruency	None	Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of participants	15	15	15	15	15	15	15
Mean	26.67	61.48	44.44	48.89	25.56	76.67	7.78
Standard deviation	9.89	15.64	23.00	24.37	25.09	16.43	10.67
Minimum	11.11	33.33	11.11	8.33	0.00	50.00	0.00
Quartile 1	22.22	55.56	27.78	33.33	8.33	66.67	0.00
Median	22.22	66.67	44.44	41.67	16.67	75.00	0.00
Quartile 3	30.56	66.67	61.11	66.67	33.33	91.67	16.67
Maximum	44.44	100.00	77.78	91.67	83.33	100.00	33.33

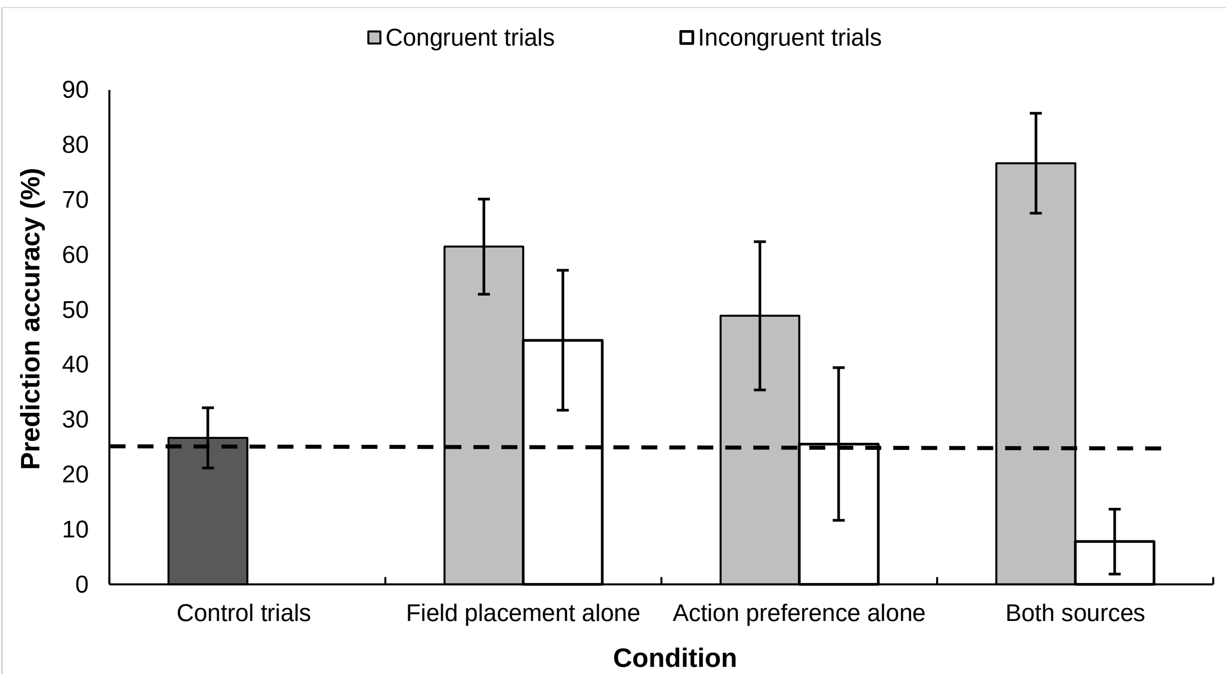

Figure 4.3- Bar graph indicating prediction accuracy (%) of batsmen when anticipating the following delivery for control trials, each condition of situational probability, as well as each category of congruency. Error bars indicate 95% confidence intervals. The dotted line represents chance level (25%) for prediction accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and prediction accuracies for each combination. Mean prediction accuracies for congruent trials of field placement alone ($t(14)=9.03$, $p<0.001$, $d=2.33$); action preference alone ($t(14)=3.80$, $p=0.002$, $d=0.98$); and both sources ($t(14)=12.18$, $p<0.001$, $d=3.14$) were significantly higher than chance level. The mean prediction accuracy for incongruent trials of field placement alone were also above chance level ($t(14)=3.27$, $p=0.006$, $d = 0.85$). In contrast, the mean prediction accuracy for incongruent trials of action preference alone was not significantly different from chance level ($t(14)=0.09$, $p=0.932$). An interesting finding was that when both sources were available but the delivery was incongruent, the mean prediction accuracy was significantly lower than chance level ($t(14)= -6.25$, $p<0.001$, $d =1.61$).

A one-way ANOVA was used to compare batsmen's prediction accuracy for control trials to all other combinations. When comparing control trials (M=26.67 ± 9.89%) to all other combinations, significant differences were found for prediction accuracy of batsmen ($F(6,98)=23.37$, $p<0.001$, $\eta_p^2= .59$). There was a large discrepancy between congruent and incongruent trials when both sources of situational probability were available, where the maximum prediction accuracies were 100% and 33% respectively (see Table 4.4).

A Dunnett post-hoc test followed the one-way ANOVA to identify where statistically significant differences were present. Post-hoc tests revealed that batsmen were significantly less accurate when predicting the delivery outcome of control trials compared to congruent trials containing field placement alone ($p<0.001$); action preferences alone ($p=0.009$); and both sources ($p<0.001$). Conversely, batsmen's prediction accuracy for control trials was significantly higher ($p=0.035$) than incongruent trials containing both sources of situational probability.

A two-way ANOVA was used in order to test for the interaction of condition and congruency for prediction accuracy of batsmen. A significant interaction effect was found between condition and congruency for prediction accuracy of batsmen ($F(2,84)=15.13$, $p<0.001$, $\eta_p^2= .26$). A Tukey HSD test was used to determine where statistically significant differences were present for prediction accuracy between the combinations of condition and congruency. The post-hoc tests revealed that batsmen's prediction accuracies were higher for congruent than incongruent trials for the action preference alone condition (p=0.023) as well as when both sources were available (p<0.001), but not for the field placement alone condition (p=0.189). When comparing conditions in terms of congruency, it was revealed that batsmen were significantly more accurate at predicting the delivery outcome of congruent trials containing both sources than congruent trials containing only the action preference (p=0.003); while the batsmen's prediction accuracy for incongruent trials containing both sources was significantly lower (p<0.001) than incongruent trials containing field placement information alone. All other interactions revealed no significant differences.

4.3. Level of Certainty Associated with Prediction Accuracy

This section provides details of results obtained regarding the level of certainty associated with prediction accuracy.

Table 4.5- Distribution (%) of levels of certainty associated with prediction accuracy for each condition of situational probability.

Certainty	Control trials	Field placement alone	Action preference alone	Both sources
1- Not at all certain	9.26	2.22	2.22	1.85
2- Slightly certain	17.04	17.78	21.48	11.85
3- Somewhat certain	36.30	40.37	37.04	32.59
4- Moderately certain	21.48	20.74	14.81	17.78
5- Extremely certain	15.93	18.89	24.44	35.93

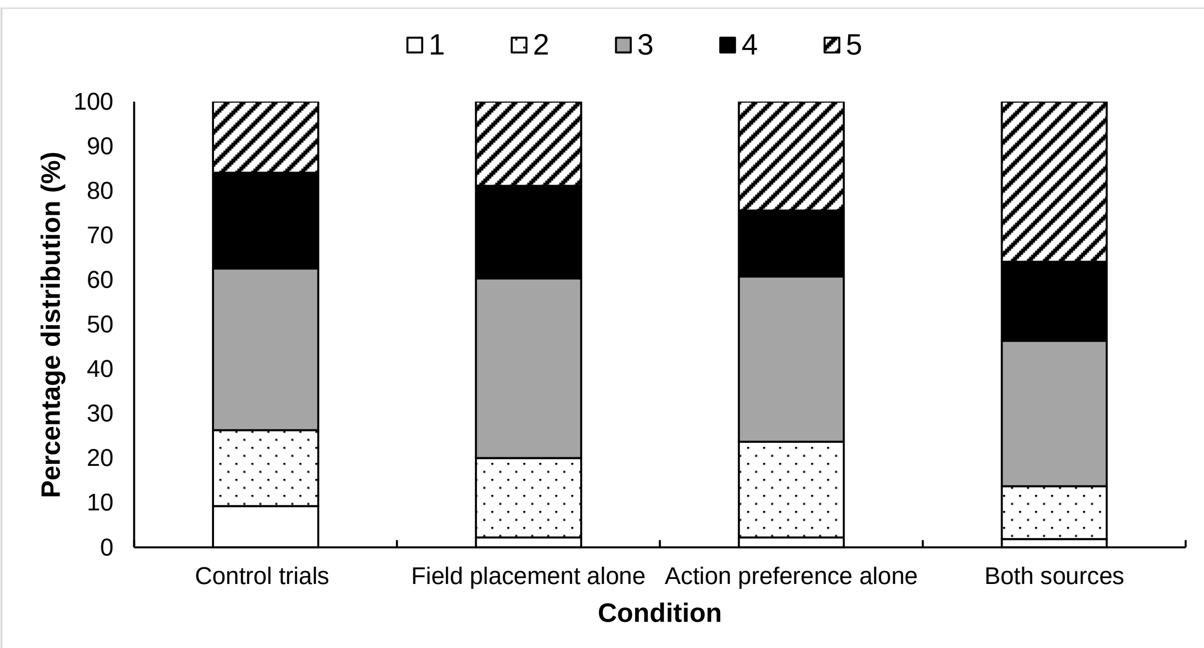

Figure 4.4- Bar graph indicating distribution (%) of levels of certainty associated with prediction accuracy for each condition of situational probability.

When both sources of situational probability information were available, the most frequently occurring certainty of correct prediction accuracy was five (extremely certain).

This was the case for 35.93% of trials containing both sources. However, in all other conditions of situational probability, ‘somewhat certain’ was the most common certainty of prediction accuracy (See Table 4.5).

4.4. Verbal Report Associated with Prediction of Delivery Outcome

This section provides details of results obtained regarding sources used to inform predictions of batsmen.

Table 4.6- Distribution (%) of sources used to predict the delivery outcome for each condition of situational probability, obtained through the verbal response.

Source/s used	Control trials	Field placement alone	Action preference alone	Both sources
Field Placement	87.78	87.41	63.33	37.04
Action Preference	0.00	0.00	17.41	20.37
Both Sources	0.00	0.37	12.22	33.70
Other	12.22	12.22	7.04	8.89

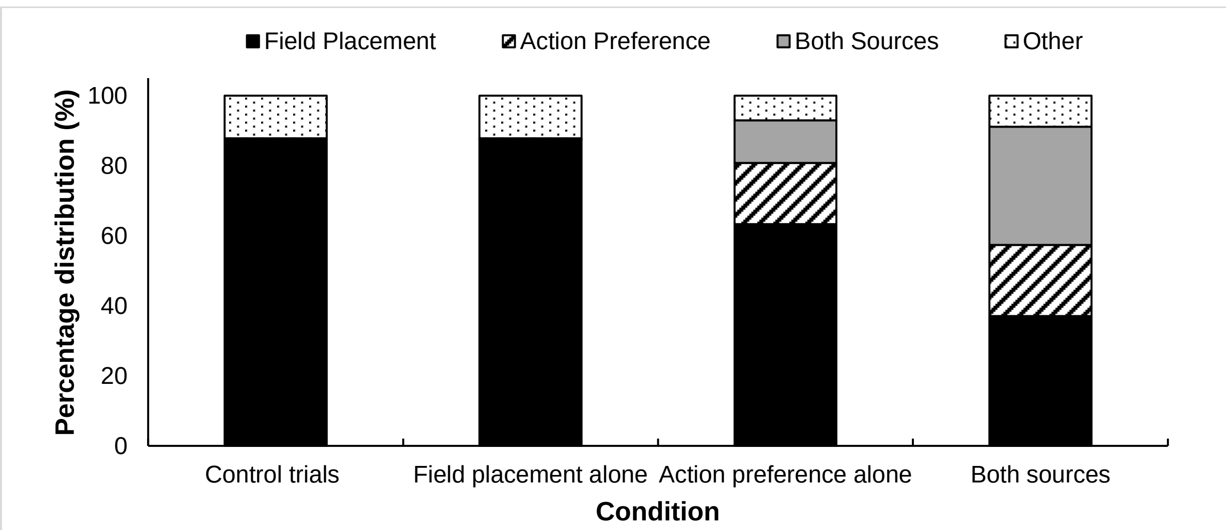

Figure 4.5- Bar graph indicating distribution (%) of sources used to predict the delivery outcome for each condition of situational probability, obtained through the verbal report.

According to Table 4.6, the use of field placements was the most frequent source used by batsmen to predict the delivery outcome, regardless of which sources of situational information was available. Field placements were used 87.78% of the time in control trials, but only 63.77% of the time when only action preferences were available, and 37.04% of the time when both sources of contextual information were available. In these conditions, batsmen made more use of other sources of information such as the action preference of the bowler or a combination of the two sources.

4.5. Response Accuracy

This section provides details of results obtained regarding the response accuracy of batsmen.

Table 4.7- Descriptive statistics regarding the overall response accuracy (%) of batsmen.

	Overall
Number of participants	15
Mean	68.24
Standard deviation	12.48
Minimum	44.44
Quartile 1	62.50
Median	66.67
Quartile 3	77.78
Maximum	83.33

This section provides details of results obtained regarding the response accuracy of batsmen.

Table 4.7 shows that response accuracy of batsmen for all trials was 68.24 ± 12.48%. A one-sample t-test revealed that this was significantly higher ($t(14)$ =5.66, p<0.001, d=1.46) than chance level (50%). The minimum prediction accuracy was 44.44% while the maximum was 83.33%, resulting in a range of 38.89%.

Table 4.8- Descriptive statistics regarding response accuracy (%) of batsmen for each condition of situational probability, regardless of congruency

	Control trials	Field placement alone	Action preference alone	Both sources
Number of participants	15	15	15	15
Mean	68.15	69.26	67.04	68.52
Standard deviation	11.78	17.04	13.68	17.90
Minimum	50.00	38.89	38.89	33.33
Quartile 1	58.33	55.56	61.11	55.56
Median	66.67	77.78	72.22	72.22
Quartile 3	80.56	80.56	77.78	80.56
Maximum	83.33	94.44	83.33	94.44

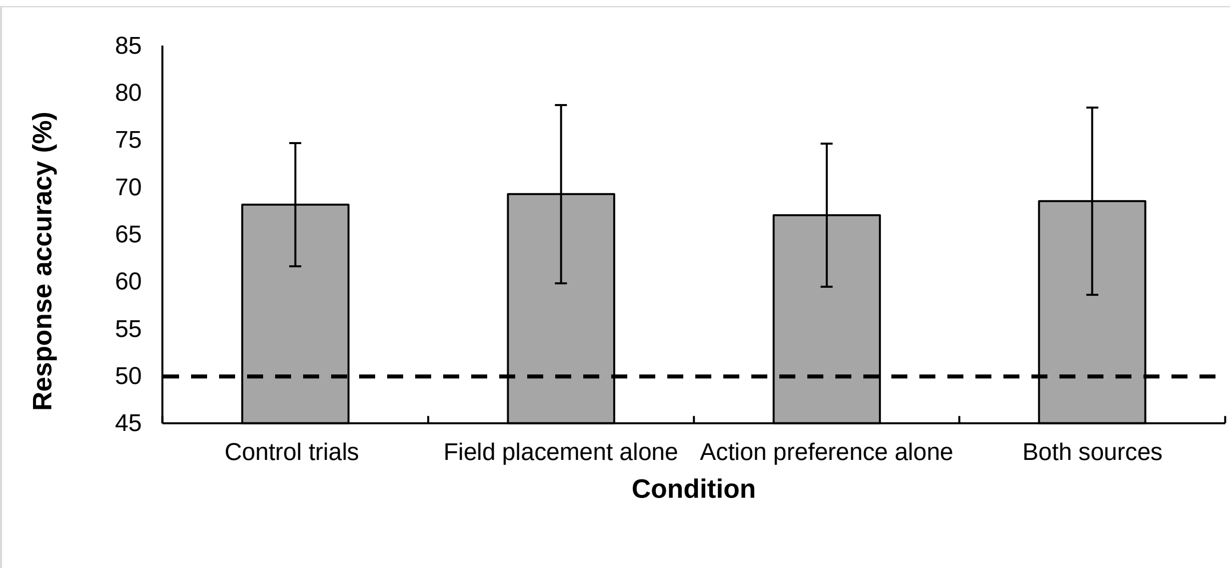

Figure 4.6- Bar graph indicating response accuracy (%) of batsmen for each condition of situational probability, regardless of congruency. Error bars indicate 95% confidence intervals. The dotted line represents chance level (50%) for response accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and response accuracy for each condition. Results reveal that the mean response accuracies for control trials ($t(14)=5.97$, $p<0.001$, $d=1.54$); trials containing field placement alone (t(14)=4.38, p=0.001, d=1.13); trials containing action preference alone (t(14) =4.82, p<0.001, d=1.25); and trials containing both sources (t(14)=4.01, p=0.001, d=1.03) were all significantly higher than chance level.

A one-way ANOVA was used to compare batsmen's response accuracy for conditions of situational probability, regardless of congruency. No significant differences were found for response accuracy between conditions of situational probability available, regardless of congruency (F(3,56)=0.055, p=0.982). According to Table 4.8, mean response accuracies for each condition were very similar and ranged between 67.04 ± 13.68% (action preferences alone) and 69.26 ± 17.04% (field placement alone). Again, there was a high level of variability of response accuracy within each condition as seen with the high standard deviations in Table 4.8.

Table 4.9- Descriptive statistics regarding response accuracy (%) of batsmen for control trials, as well as each category of congruency, regardless of condition.

	Control trials	**Congruent trials**	**Incongruent trials**
Number of participants	15	15	15
Mean	68.15	64.04	74.92
Standard deviation	11.78	19.06	13.16
Minimum	50.00	21.21	47.62
Quartile 1	58.33	56.06	69.05
Median	66.67	66.67	80.95
Quartile 3	80.56	78.79	83.33
Maximum	83.33	84.85	90.48

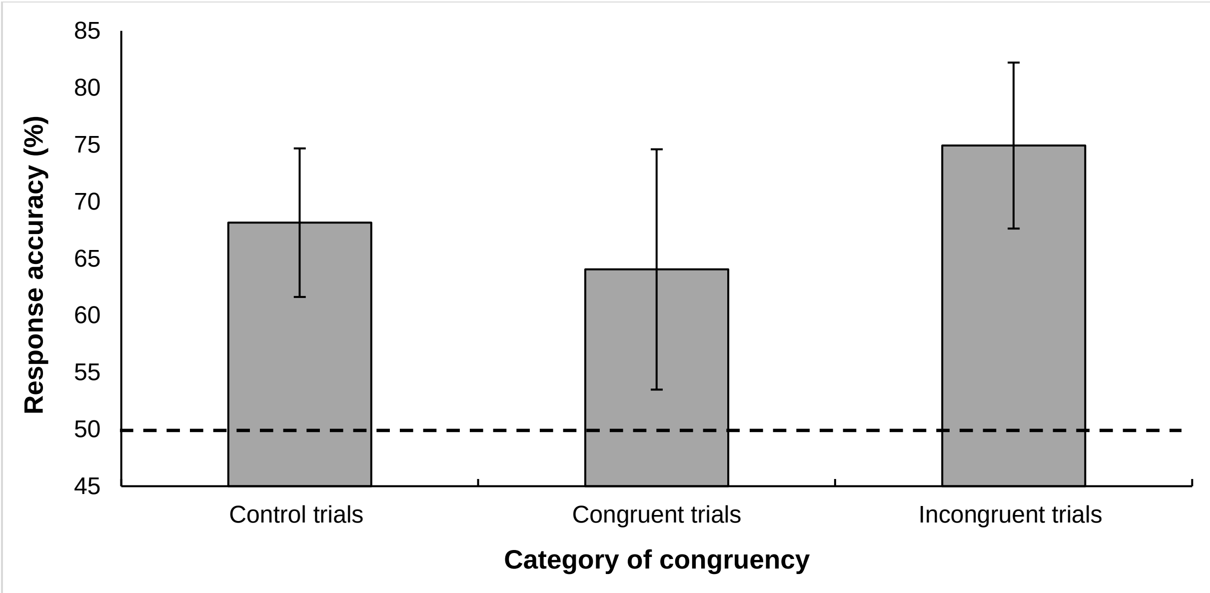

Figure 4.7- Bar graph indicating response accuracy (%) of batsmen for control trials, as well as each category of congruency, regardless of condition. Error bars indicate 95% confidence interval. The dotted line represents chance level (50%) for response accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and response accuracy for each category of congruency. Results reveal that the mean response accuracies for congruent trials ($t(14)=2.85$, $p=0.013$, $d=0.74$) and incongruent trials ($t(14)=7.33$, $p<0.001$, $d=1.89$) were significantly higher than chance level.

A one-way ANOVA was used to compare batsmen's response accuracy for congruency, regardless of conditions of situational probability. No significant differences were found for response accuracy between categories of congruency, regardless of conditions of situational probability available ($F(2,42)=2.012$, $p=0.146$). The standard deviations for each category of congruency were large, indicating large variation in response accuracy. Furthermore, it is interesting to note that the minimum response accuracy for congruent trials was only 21.21%. Minimum response accuracies for control and incongruent trials were 50.00% and 47.62% respectively (see Table 4.9).

Table 4.10- Descriptive statistics regarding response accuracy (%) of batsmen for control trials as well as congruent and incongruent trials of each condition of situational probability.

	Control trials	Field placement alone		Action preference alone		Both sources	
Congruency	None	Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of participants	15	15	15	15	15	15	15
Mean	68.15	61.48	77.04	63.33	74.44	66.67	72.22
Standard deviation	11.78	24.44	17.04	21.32	19.79	21.36	19.59
Minimum	50.00	11.11	44.44	8.33	33.33	16.67	33.33
Quartile 1	58.33	50.00	61.11	54.17	58.33	62.50	58.33
Median	66.67	66.67	88.89	66.67	83.33	66.67	83.33
Quartile 3	80.56	77.78	88.89	75.00	83.33	75.00	83.33
Maximum	83.33	88.89	100.00	91.67	100.00	100.00	100.00

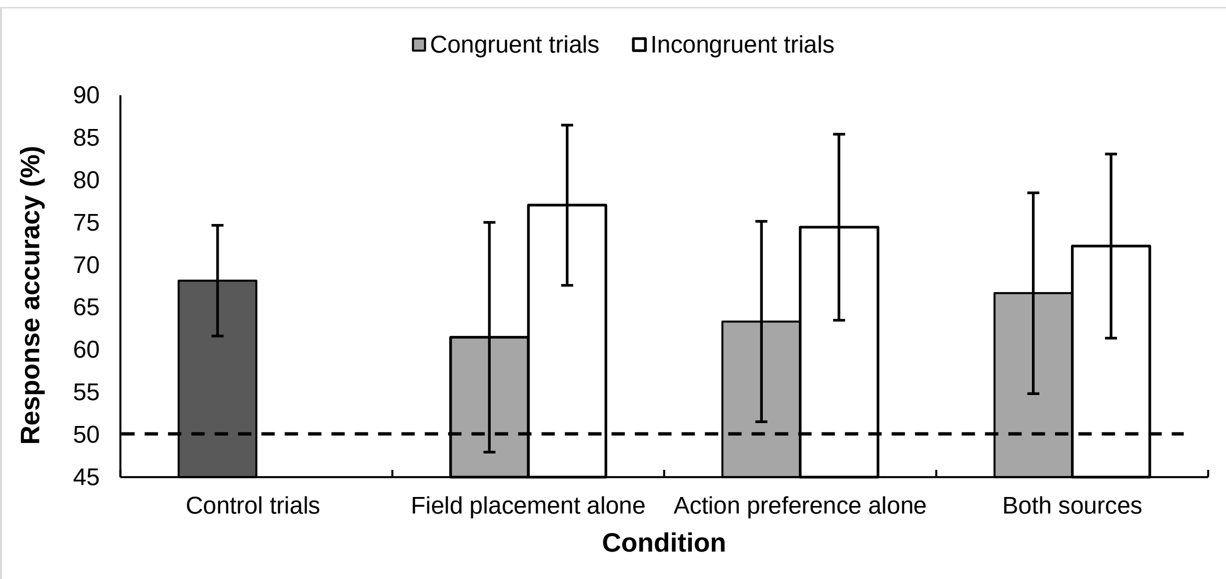

Figure 4.8- Bar Graph indicating response accuracy (%) of batsmen for control trials, each condition of situational probability, as well as each category of congruency. Error bars indicate 95% confidence intervals. The dotted line represents chance level (50%) for response accuracy.

A one-sample t-test was used in order to test for significant differences between chance level and response accuracy for each combination. Results reveal that mean response accuracies were above chance level for all combinations except for congruent trials containing field placement information alone ($t(14)=1.82$, $p=0.090$). An interesting finding was that the mean response accuracies of batsmen were greater for incongruent trials than congruent trials for each condition of situational probability, although not significant (see Table 4.10).

A one-way ANOVA was used to compare batsmen's response accuracy for control trials to all other combinations. When comparing control trials (M=68.15 ± 11.78%) to all other combinations, no significant main effect for response accuracy was found ($F(6,98)=1.287$, $p=0.270$). A two-way ANOVA was used in order to test for the interaction of condition and congruency for response accuracy of batsmen. No significant interaction effect was found between condition and congruency for response accuracy ($F(2,84)=0.439$, $p=0.646$).

4.6. Initial Movement Time

This section provides details of results obtained regarding batsmen's initial movement times. Note that some initial movement time data was lost due to invalid camera footage.

Table 4.11- Descriptive statistics regarding overall initial movement time (ms) of batsmen for all valid trials.

	Overall
Number of trials	979
Mean	5.83
Standard deviation	347.71
Minimum	-1585.00
Quartile 1	33.00
Median	150.00
Quartile 3	200.00
Maximum	384.00

According to Table 4.11, the mean initial movement time of batsmen for all trials was 5.83 ± 347.71ms while the median was 150.00ms. The minimum time taken to move following ball release was as early as -1585.00ms while the maximum was as late as 384.00ms, resulting in a range of 1969.00ms.

Table 4.12- Descriptive statistics regarding initial movement time (ms) of batsmen for all valid trials for each condition of situational probability, regardless of congruency

	Control trials	Field placement alone	Action preference alone	Both sources
Number of trials	245	243	246	245
Mean	23.10	21.77	-10.94	-34.27
Standard deviation	194.90	228.35	241.75	256.90
Minimum	-561.73	-569.80	-708.88	-804.50
Quartile 1	-32.65	18.91	-18.74	-113.18
Median	70.69	82.53	12.75	33.08
Quartile 3	155.12	153.68	164.00	109.89
Maximum	200.50	192.94	200.61	201.89

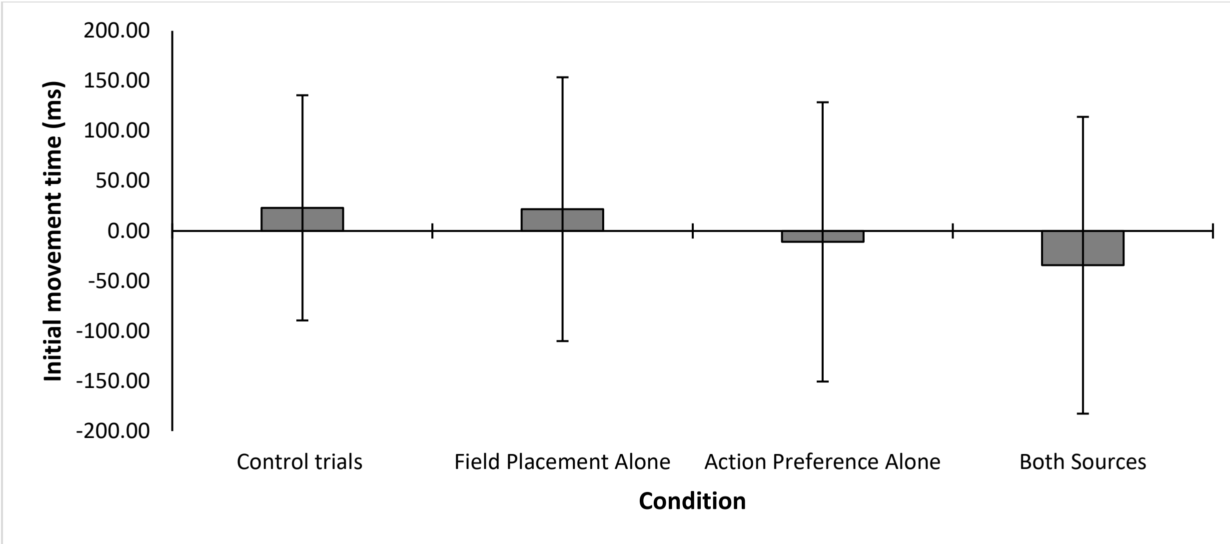

Figure 4.9- Bar graph indicating initial movement time (ms) of all valid trials of batsmen for each condition of situational probability, regardless of congruency. Error bars indicate 95% confidence intervals.

A one-way ANOVA was used to compare batsmen's initial movement time for conditions of situational probability, regardless of congruency. No significant differences were found for initial movement time between conditions of situational probability available, regardless of congruency ($F(3,52)= 0.200$, $p=0.896$).

According to Table 4.12, the mean initial movement times of batsmen for trials with field placements alone were 21.77 ± 228.35ms. Conversely, trials with action preferences alone and both sources present presented negative initial movement times of -10.94 ± 241.75ms and -34.27 ± 256.90ms respectively.

Table 4.13- Descriptive statistics regarding initial movement time (ms) of batsmen for all valid trials for control trials, as well as each category of congruency, regardless of condition.

	Control trials	Congruent trials	Incongruent trials
Number of trials	245	448	286
Mean	23.10	-31.94	29.64
Standard deviation	194.90	278.05	185.80
Minimum	-561.73	-809.33	-516.67
Quartile 1	-32.65	-38.73	-39.40
Median	70.69	-12.28	111.98
Quartile 3	155.12	144.32	151.51
Maximum	200.50	202.27	188.33

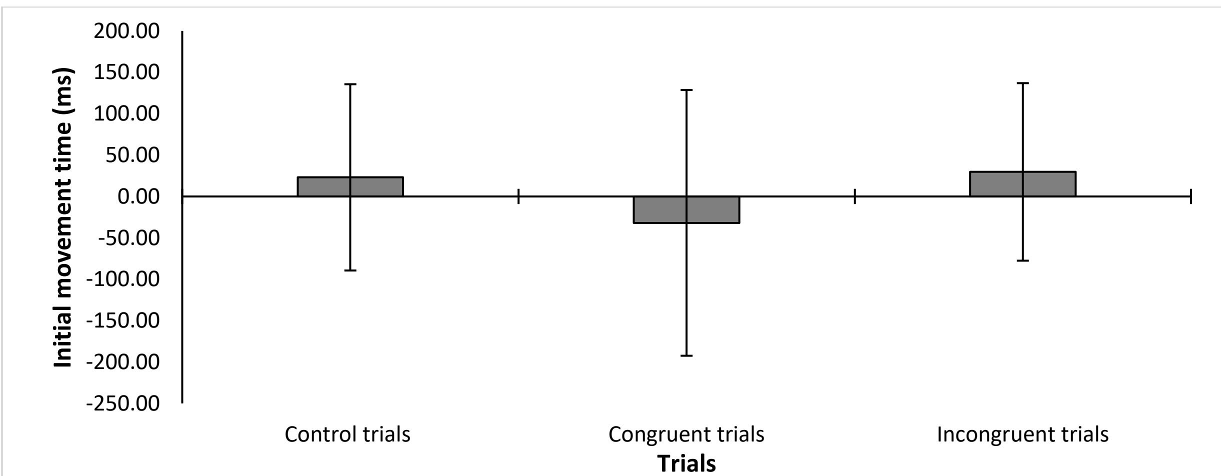

Figure 4.10- Bar graph indicating initial movement time (ms) of all valid trials of batsmen for control trials as well as each category of congruency, regardless of condition. Error bars indicate 95% confidence intervals.

A one-way ANOVA was used to compare batsmen's initial movement time for congruency, regardless of conditions of situational probability. No significant differences were found for initial movement time between categories of congruency, regardless of conditions of situational probability available ($F(2,39) = 0.321$, $p=0.728$).

When deliveries were congruent to the sources of situational probability available, the mean initial movement time of batsmen was -31.94 ± 278.05ms, while control trials and trials which were incongruent resulted in mean initial movement times of 23.10 ± 194.90ms and 29.64 ± 185.80ms respectively. Congruent trials resulted in the lowest minimum initial movement time (809.33ms) while incongruent trials resulted in the largest maximum initial movement time (202.27ms) (see Table 4.13).

Table 4.14- Descriptive statistics regarding initial movement time (ms) of batsmen for all valid trials for control trials as well as congruent and incongruent trials of each condition of situational probability.

	Control trials	Field placement alone		Action preference alone		Both sources	
Congruency	None	Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of trials	245	122	121	164	82	162	83
Mean	23.10	-14.79	60.22	-24.13	11.49	-52.54	3.54
Standard deviation	194.90	293.65	167.21	294.07	199.92	264.29	285.70
Minimum	-561.73	-755.75	-357.29	-865.20	-448.33	-794.89	-821.80
Quartile 1	-32.65	-25.53	34.35	-65.69	-71.83	-94.06	-21.58
Median	70.69	56.22	135.94	54.21	100.00	-25.75	106.50
Quartile 3	155.12	168.22	147.25	170.33	163.56	108.77	182.17
Maximum	200.50	207.78	179.67	201.92	198.00	205.58	204.33

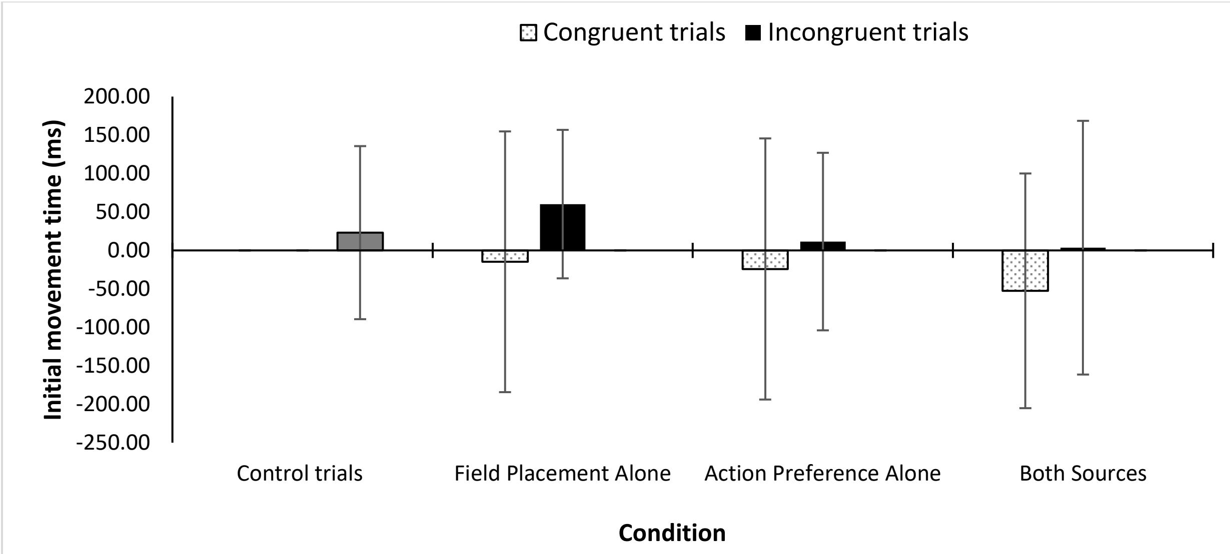

Figure 4.11- Bar graph indicating initial movement time (ms) of batsmen for all valid trials for control trials, each condition of situational probability, as well as each category of congruency. Error bars indicate 95% confidence intervals.

A one-way ANOVA was used to compare batsmen's initial movement time for control trials to all other combinations. Following this, a two-way ANOVA was used in order to test for the interaction of condition and congruency for initial movement time of batsmen. When comparing control trials to all other combinations, no significant differences for initial movement time of batsmen were found ($F(6,91)=0.298$, $p=0.936$). Furthermore, no significant interaction effect was found between condition and congruency for initial movement time of batsmen ($F(2,78)=0.04$, $p=0.959$). It is interesting to note that all mean initial movement times of batsmen for congruent combinations of each condition were negative, while the corresponding means for incongruent trials were positive. Batsmen initiated their movements the latest (M= 60.22 ± 167.21ms) when facing deliveries that were incongruent to the field placement, and earliest (M= -52.54 ± 264.29ms) when both sources of information were present, and the delivery was congruent (see Table 4.14).

The following chapter will discuss the results of this research in order to draw conclusions on hypotheses determined for this study, ultimately to indicate to what extent the aim and objectives were met.

Chapter 5: Discussion

5.1. Introduction

This study aimed to investigate the interaction between two sources of situational probability (action preferences of bowlers and opposition field placement) used by skilled cricket batsmen to anticipate the bowler's intention. An in-situ task was used in which situational probability, but not kinematic information was available for anticipation. The purpose of this chapter is to interpret and discuss the findings obtained for this study in order to reach conclusions regarding the aims and objectives. This chapter includes a discussion of the results obtained for prediction accuracy, level of certainty and verbal report associated with prediction accuracy, response accuracy, and initial movement times of batsmen. This chapter concludes with a summary of the findings of the study, limitations of the study, recommendations for future research, and a final conclusion.

5.2. Prediction Accuracy

The purpose of this section is to address the results obtained from this study in relation to the prediction accuracy of batsmen.

Runswick *et al.* (2017b) differentiate between two types of situational probability used in the current study: Situation-specific contextual information, and non-situational-specific contextual information. In order to understand which source/s of situational probability were used most effectively by batsmen to predict delivery outcome in the current study, the results were divided into the four conditions of situational probability relevant to this study (No sources, field placement alone, action preferences alone, and both sources).

According to the results collected for this study, significant differences were found between conditions of situational probability ($p<0.001$), therefore the null hypothesis for prediction accuracy is rejected (PA H_0: $PA\mu_1 = PA\mu_2 = PA\mu_3 = PA\mu_4$). Trials containing no sources of situational probability (control trials) produced the lowest mean prediction accuracy for batsmen. The mean prediction accuracy for these trials (M=26.67 ± 9.89%) was near chance level; and was significantly lower than conditions of field placement alone (p<0.001); action preferences alone (p=0.008) and both sources (p<0.001). This suggests an absence of advance information that could be used by the batsmen, resulting in guessing of the delivery outcome by the batsmen (See Figure 4.1). Therefore, since control trials which contain no sources of situational probability are significantly different from all other conditions, PA H_1, PA H_2 and PA H_3 are all accepted for the current study. This supports the findings of McRobert *et al.* (2011) who found that both skilled and less-skilled cricket batters demonstrated less error scores in a high-context condition compared to a low-context condition. It can be suggested that if situational probability information is absent, prediction accuracy will be prone to be reduced to chance level.

As highlighted by Borysiuk & Sadowski (2007), anticipation consists of a mental foreseeing of a future event based on the perception of the aim of a given activity. The mean prediction accuracy for batsmen across all trials (43.61 ± 3.59%) was significantly higher (p<0.001) than chance level (see Table 4.1). In relation to the above definition of anticipation, this result suggests that batsmen were able to make effective use of situational probability information provided (the batsmen's perception) in order to inform their predictions (mental foreseeing) of the upcoming delivery outcomes (the aim of the activity). This is consistent with research conducted by Murphy and colleagues, who found that skilled tennis players were able to use contextual information to make more accurate anticipation judgements than would be expected due to chance when no kinematic information was available (Murphy *et al.*, 2016). Furthermore, it has been established that skilled, but not less-skilled performers are able to make use of situational probability information for successful anticipation (see Farrow & Reid, 2012).

When field placement information was available to batsmen their mean prediction accuracy was 52.96 ± 10.68%. Since prediction accuracy was significantly greater than chance level (p<0.001), this provides evidence that field placement information is a relevant source of situational probability information in cricket and is supported by research by Runswick *et al.* (2018a). Additionally, these results provide an indication that the batsmen in this study were at a skill level high enough to effectively interpret and utilize the field placement information implicitly provided to them as a source of situational probability in order to predict the delivery outcome.

Previous research in tennis (Farrow & Reid, 2012) and squash (Abernethy *et al.*, 2001) showed that skilled, but not unskilled participants were able to make use of implicit situational probability information provided. It could be expected that if the batsmen in the current study were not skilled enough, the prediction accuracy under the field placement condition may have been closer to chance level. Situational probability information is used by adult skilled performers to build a knowledge base (condition framework) that is stored and retrieved from long term memory and is regularly updated based on their own performance and that of their opponents (McPherson, 2013). Moreover, the current study supports the suggestion made by Müller and Abernethy (2012) that skilled performers may implicitly generate situational probabilities based on context. It is likely that senior club-level batsmen are able to retrieve task-relevant information from long term memory based on their experience and use it to interpret the opposition field placement as an indication of a probable delivery outcome.

When information regarding the action preference condition was explicitly provided to batsmen, their mean prediction accuracy was 41.11 ± 15.83%. Considering prediction accuracy was significantly greater than chance level (p=0.001) as well as control trials (p = 0.008), this provides evidence that action preference information is a relevant source of situational probability information in cricket batting. However, trials containing information regarding action preferences alone had a significantly lower prediction accuracy than trials containing field placement information (p=0.042) and trials containing both sources (p=0.028). Therefore, PA H_4 and PA H_5 can be accepted for the current study. This can be seen as a surprising result as explicit information was provided to batsmen regarding the action preference condition, while implicit information was used by batsmen in the field placement condition.

A possible explanation is that while batsmen were able to make use of a framework stored in long term memory to anticipate delivery outcome during the field placement alone condition when action preference information was available batsmen were not able to rely on any implicit framework as the action preference information was explicitly provided by the researcher. Explicit information regarding the action preference condition may encourage skilled performers to make use of strategies that are less reliable than ones that they would typically use (i.e., field placement information). It is possible that by expecting one particular action-outcome to occur, skilled performers may be less likely to use information that they have relied on consistently throughout their development to anticipate their opponent's actions (Mann *et al.*, 2014). It can be suggested that the field placement indicating a short, legside delivery provided much more relevant probabilistic information compared to other field placements shown to batsmen during control trials or action preference alone trials. Furthermore, the batsmen may not have trusted the information provided about the action preference condition; while the field placement information could be trusted as it matched information in their knowledge base which had been built up with playing experience. It is likely that the batsmen in the study took some time to assess the truthfulness of the action preference information, and in this time, valued their implicit knowledge on field placements over the explicit action preference information.

However, the prediction accuracy of batsmen when action preference information was available was above chance level and control trials which means than when no other sources of situational probability information were available, batsmen considered the information provided. Contextual information has been found to enable the ability to predict events in sport by making it possible to dismiss many events as highly improbable (Crognier & Féry, 2005). Batsmen were aware that the likelihood of facing a short, legside delivery was much greater than any other type of delivery and were able to rule out, to some degree, the possibility of any other delivery but the type specified by the action preference. These results support those of Gredin, Bishop, Broadbent, Tucker and Williams (2018) who suggested that the impact of providing explicit information regarding probabilistic information is dependent on the ability of the performer to use this information. Furthermore, these findings may have practical implications as improved availability of technology has provided a means for detailed analyses of forthcoming opponent's action preferences; hence the explicit provision of contextual information has become an important component of elite sport. Since there is a difference between how skilled batsmen use explicit and implicit information in this study, it might be worth investigating how expertise influences the use of implicit and explicit information respectively.

While it has been established that the addition of contextual information to kinematic information positively influences anticipation, this study attempted to address the call made by McRobert *et al.* (2011) and Runswick *et al.* (2017a) to systematically increase the amount of contextual information presented to participants in order to mimic the demands of actual competition. According to Figure 4.1 when both sources of situational probability information were available, the mean prediction accuracy was 53.70 ± 10.43%. This was significantly higher than chance level ($p<0.001$) and control trials ($p<0.001$). It is interesting to note that although batsmen were more accurate when predicting trials containing field placement alone and both sources of situational probability than when action preference information was alone, there was no significant difference in prediction accuracy between both sources and field placement alone. Therefore, PA H_5 can be rejected for the current study. This could suggest that it is not necessarily the number of sources present, but rather the relevance of the source that is most important for a batsman to predict the outcome of a delivery. However, this result compares two different methods of providing situational probability (implicit vs explicit). Therefore, it could be worth investigating the effect of situational probability when different sources of information are provided in the same manner.

It has been reported that soccer players draw upon more pertinent kinematic information variables according to the relevance to the task at hand (Savelsbergh *et al.*, 2005). It is possible that this phenomenon could also apply to situational probability information. In relation to the current study, regardless of whether batsmen were provided with both sources (two sources) or field placement information alone (one source), their prediction accuracy was higher than when provided with action preferences alone (one source). Hence, field placement information may be considered by batsmen to be one of the most relevant sources when predicting the subsequent delivery outcome in cricket. This may be a result of the nature of the different sources of situational probability. Field placement information is more specific as it applies to each delivery outcome, while action preference information is a lot more general in nature as it not clear which deliveries will correspond with the action preference information. Furthermore, these findings may also support Runswick *et al.* (2018b) who found that adding multiple sources of context to a complex task did not affect the levels of mental effort expended by skilled performers. Hence, whether one or two sources of situational probability information were available for batsmen in the current study, this did not negatively influence their ability to make successful predictions of the delivery outcome.

The results in the present study suggest that batsmen were able to use implicit domain-specific knowledge from long term memory (use of field placement information) and continuously combine it with explicit incoming information (action preference information) in order to make successful predictions of the delivery outcome.

This study also investigated the effect of delivery outcome congruency on batsmen's prediction accuracy. According to Figure 4.2, results revealed that batsmen predicted more accurately (M=62.42 ± 8.86%) when the delivery outcome was congruent to the sources of situational probability available. During control and incongruent trials, the prediction accuracy of batsmen was close to chance level. During these incongruent trials, the batsmen were using the situational probability information to inform their predictions, however, they were not aware that the delivery outcome was incongruent until after the ball had been delivered as the pitching position of the delivery provided feedback of delivery type. This resulted in their predictions of these trials being incorrect at times and therefore making a prediction on incongruent trials was no different to guessing what the event outcome would be.

These results are in line with those of Runswick *et al.* (2018a) who found that regardless of skill-level, cricket batsmen were able to anticipate delivery outcome more accurately in congruent compared to incongruent conditions. Similarly, the findings of the present study are in support of Mann *et al.* (2014) in handball; Gredin, Bishop, Broadbent, Tucker & Williams (2018) in soccer; and Canãl-Bruland *et al.* (2015) in baseball batting, who showed that contextual information of an opponent could harm the anticipatory baseball batting performance when the information is not congruent with the event outcome.

The interaction of condition and congruency was also investigated in order to understand the effect that congruency of delivery had on prediction accuracy for each condition of situational probability available. A significant interaction effect was found between condition and congruency for the prediction accuracy of batsmen ($p<0.001$). It was revealed that batsmen's prediction accuracies were significantly higher for congruent than incongruent trials for the action preference alone condition ($p=0.023$) as well as when both sources were available ($p<0.001$)(See Figure 4.3). However, non-significant performance differences were found for prediction accuracy between congruent (M=61.48 ± 15.64%) and incongruent (M=44.44 ± 23.00%) trials containing field placement information alone. This is an interesting finding as differences in congruency for field placement information did not have the same effect as the other two conditions. Although the field placement for these trials was designed to emphasize one type of delivery (short, legside delivery), it may not have been distinct enough to be associated with that type of delivery alone. This could have resulted in a large variation in prediction accuracy for incongruent trials, resulting in the absence of a significant difference.

Finally, the cost of anticipation when the action-outcome is incongruent to the information available was further emphasized by the prediction accuracies for incongruent trials of action preference alone and both sources which were the same (M=25.56 ± 25.09%) and significantly lower (M=7.78 ± 10.67%) than chance level respectively. This suggests that when a delivery outcome is incongruent to the situational probability available, it is similar to, or more detrimental than having no situational probability sources available for anticipation.

5.3. Level of Certainty Associated with Prediction Accuracy

In this study, batsmen were asked to rate the certainty of their prediction according to a five-point Likert scale. This section aims to discuss the results obtained from this study in relation to the level of certainty associated with prediction accuracy for the conditions of situational probability provided.

Table 4.5 indicates the percentage distribution of each level of certainty for the different conditions in this study. The most frequently occurring certainty for each condition except for Both sources was “somewhat certain”. When both sources were available, batsmen predominantly “extremely certain” that their prediction was correct (35.93% of the time). A likely reason for the neutral response for most conditions is that a conservative approach could have been used by batsmen when asked about their certainties. This could prove true, especially for trials in which action preference information was provided as this information was explicitly provided and therefore the batsmen might not have necessarily trusted this information to be true. Furthermore, batsmen are often encouraged to play each ball on its merit. In other words, it is often discouraged for a batsman to have any bias towards an upcoming delivery before it is bowled.

It is interesting to note that when both sources of situational probability were available, not only was the prediction accuracy the greatest, but batsmen were also found to be more certain about the accuracy of their predictions. These findings are broadly in line with Alain and Sarrazin (1990), who found a strong relationship between the participants’ subjective assessment and the subsequent anticipatory movements. It is likely that a Bayesian rule was applied by batsmen when both sources of situational probability information were available (See Vilares & Kording (2011) and Knill & Pouget (2004) for more information on Bayesian rules).

5.4. Verbal Report Associated with Prediction of Delivery Outcome

Before facing each delivery in this study, batsmen were asked what information they used in order to make their prediction of the delivery outcome. The purpose of this section is to discuss this verbal report in terms of conditions of situational probability information provided.

According to Table 4.6, the information that batsmen used most frequently to inform their predictions was field placement information (Situation-specific contextual information). This was the case for all conditions of situational probability provided. A possible explanation could be that field placement information was consistently present for each delivery, regardless of whether it was suitable for the outcome of the subsequent delivery (i.e., during control trials, the field placement provided did not suggest any particular type of delivery). However, although action preference information was provided to batsmen during data collection, it was less consistent as participants were not aware of which deliveries to which it applied (batsmen only knew that it the bowler bowled short, legside deliveries 67% of the time).

Similar results were found by Runswick *et al.* (2017b) who showed, through the use of a verbal report, that skilled and less-skilled cricket players used field placement information more than any other contextual source available. It is plausible that, if Runswick and colleagues had not included kinematic information for batsmen, the number of references pertaining to field placement information could have been even more prominent. Again, it can be suggested that field placement information is more specific as it applies to each delivery outcome, while action preference information is a lot more general in nature as it not clear which deliveries will correspond with the action preference information. This may provide evidence that the means by which information is provided to a batsman may be an important factor when providing batsmen with situational probability information.

The verbal report indicated that batsmen used field placement information most frequently even during trials containing action preferences alone. Furthermore, it was established that batsmen’s prediction accuracy was lower when action preference information was available compared to field placement information. This could suggest that identifying the correct source of situational information to use is a vital part of correct anticipation and that failure to do so could be to the detriment of the batsman. These findings as a whole extend and support the work of Loffing and Hagemann (2014a) as well as Runswick *et al.* (2017b) by showing that the positions of opponents who do not necessarily play the ball themselves still affect anticipation and the underlying cognitive processes involved.

As expected, during control trials and trials containing field placement information alone, batsmen did not make use of action preferences to inform their predictions. This is due to the fact that these trials were delivered by the “opponent” who did not have an action preference in this study. In the action preference alone and both sources conditions, action preference information was used second and third most frequent respectively. This suggests that batsmen did value this information when making their predictions. It is interesting to note that although the conditions of situational probability provided to batsmen were used to inform their prediction of delivery outcomes, other information was also used to a smaller extent. This finding could be a call to investigate further other potential sources of situational probability not included in this study that a batsman may use when predicting delivery outcome.

5.5. Response Accuracy

The in-situ nature of this study allowed for an integration of ventral vision for perception (prediction accuracy) and dorsal vision for action (response accuracy). The purpose of this section is to address the results obtained from this study in relation to the response accuracy of batsmen. Response accuracy provided an indication of how often batsmen were able to strike the ball successfully.

Similar to the findings on prediction accuracy, the mean response accuracy across all trials for all batsmen was higher than chance level (see Table 4.7). This suggests that the batsmen used for this study were at a suitable skill-level for this study and their ability to strike the ball was not based on chance but rather an inherent degree of perceptual-motor skills and action capabilities. While the ventral system is assumed to be more engaged before movement onset, the dorsal system involvement dominates from movement onset. The ventral stream has different sources of visual information such as the opponent's movement kinematics, the opponent's positioning, and possibly early ball flight (Van der Kamp *et al.*, 2008). Since kinematics of the opposition were not available in the current study, it is possible that dorsal vision used to guide movement execution was predominant.

No main or interaction effects were found for response accuracy. According to the results collected for this study, the null hypothesis for response accuracy is accepted as conditions of situational probability were not significantly different to each other. Mann and colleagues suggested that it could be reasonable to expect that knowledge about situational probability information (in their case, action preference of an opponent) could lead to strong changes in response accuracy when producing a motor response, particularly when the time constraints become more demanding (Mann *et al.*, 2014). Although this was a hypothetical suggestion, the current study attempted to address this phenomenon. Although significant differences in prediction accuracy were found, when investigating the differences in response accuracies of batsmen, no significant differences were found. These results support the alternative theory suggested by Mann and colleagues, who proposed that it is possible that the strong perception-action coupling inherent in a motor response may be more resistant to disruption by situational information than a perceptual response. Since all conditions in the current study resulted in response accuracies above chance level, but no different to each other, it can be suggested that a motor response (in this case, response accuracy) may be less influenced than a perceptual response (prediction accuracy) by conscious knowledge of probabilistic information.

This study provided no kinematic cues for the batsmen to use when attempting to strike the ball successfully. Therefore, the only information besides situational probability was ball flight information. Since skilled batsmen are able to rapidly correct responses formulated from the use of context after 80ms of ball flight information (Runswick *et al.*, 2018b), batsmen in the current study were able to successfully strike the ball despite potential incorrect predictions of the delivery outcome which could also explain why no significant differences were found for response accuracy. This supports the notion that ball flight information is especially important for precise, fine-tuning of the upper-body interceptive action of cricket batting (Müller & Abernethy, 2006; Müller & Abernethy, 2012). Triolet *et al.* (2013) argued that anticipation (prediction accuracy) is based on uncertain information, which in some cases can lead to erroneous decisions, while reaction is based on certain information which often results in high response accuracy. Additionally, in some cases, the cost of anticipating incorrectly may be far too great and therefore some performers anticipate infrequently, perhaps only when time constraints are too severe (Williams, 2009). It is plausible that the delivery speeds in the current study were not high enough to impose the need of anticipation on the batsmen attempting to strike the ball and therefore no differences in response accuracy were found between or within the conditions of situational probability.

In relation to prediction accuracy, the present study supports Runswick and colleagues who argued that confirmation bias can explain why contextual information can have both positive and negative effects on anticipation performance (Runswick *et al.*, 2018a). It was found that congruent combinations generally produced higher prediction accuracies, while incongruent combinations resulted in prediction accuracies equal to, and even below chance level. However, confirmation bias cannot be used to explain the results found in relation to response accuracy in this study. Confirmation bias suggests that once a decision has been made, people prefer to focus on supporting information and avoid information that conflicts with that originally presented (Jonas, Schulz-hardt, Frey & Thelen, 2001). Had significant differences been found in response accuracies between different conditions of situational probability, then confirmation bias could have been a possible explanation. Runswick speculated that confirmation bias in anticipation could transfer to the interceptive response. It was suggested that even if early ball flight was not subject to confirmation bias then the batter is at a disadvantage as the correct outcome is realised later, providing less time to execute the motor response. However in the present study (although at medium delivery speeds), there were no differences in response accuracy regardless of the category of congruency or condition of situational probability despite the corresponding prediction accuracy differences. Therefore, it is suggested that the effects displayed by Runswick and colleagues do not occur when ball flight information is available. However, in the future, the effect of delivery speed on response bias could be investigated further.

Furthermore, it is interesting to note that non-significant performance differences were found for response accuracies between congruent and incongruent trials for each condition of situational probability. Although Runswick and colleagues attempted to use congruent and incongruent information to explain 'why bad balls get wickets,' this may not always be the case. The pen and paper response used by Runswick *et al.* (2018a) used with a screen-based stimulus potentially negates the action capabilities of skilled batsmen and makes it difficult to transfer findings to the field setting. The in-situ nature of the current study allowed response accuracy to be assessed along with an assessment of anticipation similar to that of Runswick *et al.* (2018a). Since there was no apparent effect on response accuracy regardless of congruency, it can be suggested that incongruent (bad) deliveries do not necessarily take wickets in a match situation. In future, researchers could investigate under which circumstances (eg., delivery speeds) the congruency of the delivery could have an effect on response accuracy.

Finally, it was generally found that the mean response accuracy for incongruent trials was non-significantly higher than congruent trials for each condition. A reason for this could be that a congruent delivery was one that was pitched short and legside while incongruent trials were delivered to pitch in one of the other four quadrants of the pitch. This type of delivery is generally one that is more difficult to strike, possibly because a ball that bounces shorter, and thus earlier, reaches critical velocity far sooner and allows less pursuit tracking for the batsman pre-bounce (Land & McLeod, 2000) and the post-bounce extrapolation of is longer (Müller & Abernethy, 2006). Additionally, due to the uneven pace and bounce of the ball caused by the nature of the pitches used for testing, these congruent trials proved even more challenging for batsmen to strike.

5.6. Initial Movement Time

The purpose of this section is to address the results obtained from this study in relation to initial movement time of batsmen. Initial movement time (IMT) was considered as the time between ball release and the first recorded movement of the batsman, as supported by Peploe *et al.* (2014). The mean overall IMT in this study was found to be 5.83 ± 347.71ms. These results are not entirely consistent with similar studies which evaluated the movement timing of batsmen when facing a bowling machine. For example, Peploe *et al.* (2014); Pinder *et al.* (2009) and Renshaw *et al.* (2007) found mean IMT's of 5ms; 140ms; and 160ms respectively. However, participants in these studies were only required to face full-pitched deliveries and had not been provided with any situational probability information.

It was expected that initial movement time would be later when no sources of situational probability were available compared to other conditions as this was the case in tennis (Triolet *et al.*, 2013); soccer (Navia *et al.*, 2013) as well as squash (Abernethy *et al.*, 2001). Triolet and colleagues (2013) found that when no probabilistic information was available, tennis players waited longer and potentially made anticipatory responses based on the postural orientation of the opponent or ball flight information.

However, when investigating the differences in initial movement times of batsmen, no significant differences were found within conditions of situational probability and categories of congruency, or between combinations thereof despite the differences in prediction accuracy. According to the results obtained for this study, the null hypothesis for initial movement time cannot be rejected as no conditions of situational probability were significantly different to each other. Moreover, other studies in the field of anticipation in the presence of situational probability information have shown improvements in perception, but not necessarily action accuracy or timing due to the nature of the lab-based studies (See Farrow & Reid, 2012; McRobert *et al.*, 2011).

When investigating IMT in terms of conditions of situational probability available, it was found that on average, batsmen initiated their movements prior to ball release when action preference information or both sources were available (both ‘opponent two’). In contrast, during control trials and trials in which field placement information was available (both ‘opponent one’), batsmen initiated their movements after ball release. This could relate to the high certainty of prediction accuracy that batsmen had when both sources of situational probability were available. It is possible that during these trials, batsmen were comfortable to make preparatory movements prior to ball release as there was enough evidence to suggest that these deliveries were most likely going to be pitched in a certain part of the pitch.

It is interesting to note that although not significantly, mean initial movement times were smaller (i.e., faster) for congruent combinations of each condition than incongruent combinations (See Figure 4.11). Similarly, batsmen were more accurate when predicting the delivery outcome of congruent combinations of each condition. This could indicate that for congruent trials, during ball flight, shortly after the ball exited the bowling machine and the batsmen’s correct predictions were confirmed, they were able to move into the most advantageous position for bat-ball contact at an earlier stage compared to incongruent trials.

Although no differences in initial movement times were found between conditions or categories of congruency, similar research in baseball has found that expectations (possibly informed by situational probability information) can influence motor responses in highly time-constrained situations (Cañal-Bruland *et al.*, 2015). For example, Mann *et al.* (2014) found improvements for handball players in both anticipation and response time when there was congruence between the expected and actual outcome of an opponent’s actions; but a decrease in anticipation accuracy without a change in response time during incongruent trials. In future, it could be useful to investigate the timing of batsmen's movement patterns (eg., backswing and front foot movements) in relation to situational probability in addition to initial movement time in isolation.

5.7. Findings and Summary of Results

This section highlights the findings of this study according to the statistical hypotheses as well as a summary of the main results in terms of batsmen's prediction accuracy, response accuracy, and initial movement time.

5.7.1. Prediction Accuracy

The findings of this study according to the statistical hypotheses stated for prediction accuracy are as follows:

PA H_0: $PA\mu_1 = PA\mu_2 = PA\mu_3 = PA\mu_4$

The null hypothesis (PA H_0) can be rejected.

PA H_1: $PA\mu_1 \neq PA\mu_2$

The alternative hypothesis (PA H_1) cannot be rejected and is therefore accepted.

PA H_2: $PA\mu_1 \neq PA\mu_3$

The alternative hypothesis (PA H_2) cannot be rejected and is therefore accepted.

PA H_3: $PA\mu_1 \neq PA\mu_4$

The alternative hypothesis (PA H_3 cannot be rejected and is therefore accepted.

PA H_4: $PA\mu_2 \neq PA\mu_3$

The alternative hypothesis (PA H_4) cannot be rejected and is therefore accepted.

PA H_5: $PA\mu_2 \neq PA\mu_4$

The alternative hypothesis (PA H_5) cannot be rejected and is therefore accepted.

PA H_6: $PA\mu_3 \neq PA\mu_4$

The alternative hypothesis (PA H_6) can be rejected.

Prediction accuracy of batsmen was significantly greater than chance level (25%) for all conditions of situational probability provided but not for control trials. Results revealed that prediction accuracy for batsmen was significantly higher for field placement alone compared to the action preference alone condition. Furthermore, when both sources of situational probability information were present, batsmen's prediction accuracy was significantly higher than the action preference alone condition, but not for the field placement alone condition.

When the outcome of the delivery was congruent to contextual information provided, the prediction accuracy of batsmen was significantly higher than chance level as well as control and incongruent trials. Additionally, control trials and incongruent were not significantly different from chance level. Mean prediction accuracies for congruent trials of field placement alone; action preference alone; and both sources were significantly higher than chance level. An interesting finding was that the mean prediction accuracy of batsmen for incongruent trials containing field placement information was also significantly higher than chance level. When action preference information or both sources were available, but the delivery was incongruent, mean prediction accuracies of batsmen were the same and significantly lower than chance levels respectively. Batsmen were significantly less accurate when predicting the delivery outcome of control trials compared to congruent trials containing field placement alone; action preferences alone; and both sources. Conversely, batsmen's prediction accuracy for control trials was significantly higher than incongruent trials containing both sources of situational probability. Batsmen's prediction accuracies were higher for congruent than incongruent trials for the action preference alone condition as well as when both sources were available, but not for field placement alone. Results also revealed that batsmen were significantly more accurate at predicting the delivery outcome of congruent trials containing both sources than congruent trials containing only the action preference; while the batsmen's prediction accuracy for incongruent trials containing both sources was significantly lower than incongruent trials containing field placement information alone.

In terms of batsmen's level of certainty associated with prediction accuracy, the most frequently occurring level of certainty for trials with no sources, field placement information alone and action preference information alone was 'Somewhat certain'. In contrast, the most frequently occurring level of certainty for trials containing both sources was 'Extremely certain'. The use of field placements was the most frequent source used by batsmen to predict the delivery outcome, regardless of which sources of situational information were available.

5.7.2. Response Accuracy

The findings of this study according to the statistical hypotheses stated for response accuracy are as follows:

RA H_0: $RA\mu_1 = RA\mu_2 = RA\mu_3 = RA\mu_4$

RA H_1: $RA\mu_1 \neq RA\mu_2$

RA H_2: $RA\mu_1 \neq RA\mu_3$

RA H_3: $RA\mu_1 \neq RA\mu_4$

RA H_4: $RA\mu_2 \neq RA\mu_3$

RA H_5: $RA\mu_2 \neq RA\mu_4$

RA H_6: $RA\mu_3 \neq RA\mu_4$

The null hypothesis (RA H_0) cannot be rejected and is therefore accepted, and all alternative hypotheses can be rejected.

The mean response accuracy across all trials for all batsmen was higher than chance level. There were no significant differences in batsmen's response accuracy in terms of conditions of situational probability, categories of congruency, or combinations thereof. An interesting finding was that the mean response accuracies of batsmen were greater for incongruent trials than congruent trials for each condition of situational probability, although not significant.

5.7.3. Initial Movement Time

The findings of this study according to the statistical hypotheses stated for initial movement time are as follows:

IMT H_0: IMTμ_1 = IMTμ_2 = IMTμ_3 = IMTμ_4

IMT H_1: IMT$\mu_1 \neq$ IMTμ_2

IMT H_2: IMT$\mu_1 \neq$ IMTμ_3

IMT H_3: IMT$\mu_1 \neq$ IMTμ_4

IMT H_4: IMT$\mu_2 \neq$ IMTμ_3

IMT H_5: IMT$\mu_2 \neq$ IMTμ_4

IMT H_6: IMT$\mu_3 \neq$ IMTμ_4

The null hypothesis (IMT H_0) cannot be rejected and is therefore accepted, and all alternative hypotheses can be rejected.

In terms of initial movement times of batsmen, there were no significant differences within conditions of situational probability; categories of congruency; or combinations of condition and congruency.

5.8. Limitations

Despite the positive results of this study, there were several limiting factors that could have had an effect on the outcomes of the study.

- The nature of the quasi-experimental design limits the current study's ability to conclude a causal association between the conditions and the outcome.

- The sample size was limited. This was due to the fact that only the top six batsmen from the cricket clubs were considered for this study, and that not all of these clubs were situated in close proximity of the testing venue.

- Cognitive and visual assessments (i.e., visual screening) were not conducted for participants prior to testing.

- Participants' previous experience facing a bowling machine was not controlled.

- Mechanical performance of the bowling machine could have decreased over time of testing.

- The method of asking questions before each delivery was not validated prior to the current study.

- The number of trials was limited and did not account for an equal number of successful and unsuccessful trials in terms of prediction or response accuracy.

- Since an in-situ study design was used, environmental conditions varied between testing sessions. Changes in weather and outdoor pitch conditions resulted in differing levels of difficulty when attempting to strike the ball, which may have had an effect on response accuracies.

- Due to the slow nature of the cricket pitches used, the balls lost pace once they made contact with the surface. This allowed the participants more time to play their desired shots and may have had an effect on response accuracies.

- Since the situational probability information for the action preference condition was provided explicitly to the participants rather than implicitly discovered, the participants may have used some of the early trials to assess the reliability of the information provided. This may have influenced the prediction accuracies, particularly in the early stages of the testing procedure.

- It is possible that the delivery speed of the ball was not fast enough to induce the batsmen to use anticipation when attempting to strike the ball.

5.9. Recommendations for Further Research

For future studies it is recommended that the current research is repeated and the following to be considered:

- Increase the sample size and number of trials.
- Conduct the testing on an artificial indoor cricket pitch in order to minimize variability in environmental conditions.
- Use a different type of delivery for the action preference of the bowler. A short ball was used in this study; however, this may not be specific to the game of cricket as only two short balls are allowed per over in cricket, and these types of deliveries are considered more challenging to play than fuller balls.
- Increase the speed of ball delivery

5.10. Conclusion

The conclusion for this study provides a summary of all results and discussions in order to achieve the main aims and objectives of the present study.

The following can be concluded for the present study:

Skilled cricket batsmen were able to use situational probability information to anticipate the intentions of the bowler. When field placement information was available, batsmen's prediction accuracy was significantly higher than when action preference information was available. Therefore, it appears that field placement information is valued more by batsmen than action preference information. When both sources of situational probability were available, batsmen's prediction accuracy was significantly higher than in the action preference alone condition; but not for the field placement alone condition. Finally, the conditions of situational probability available for batsmen were not significantly different to one another in terms of response accuracy or initial movement time.

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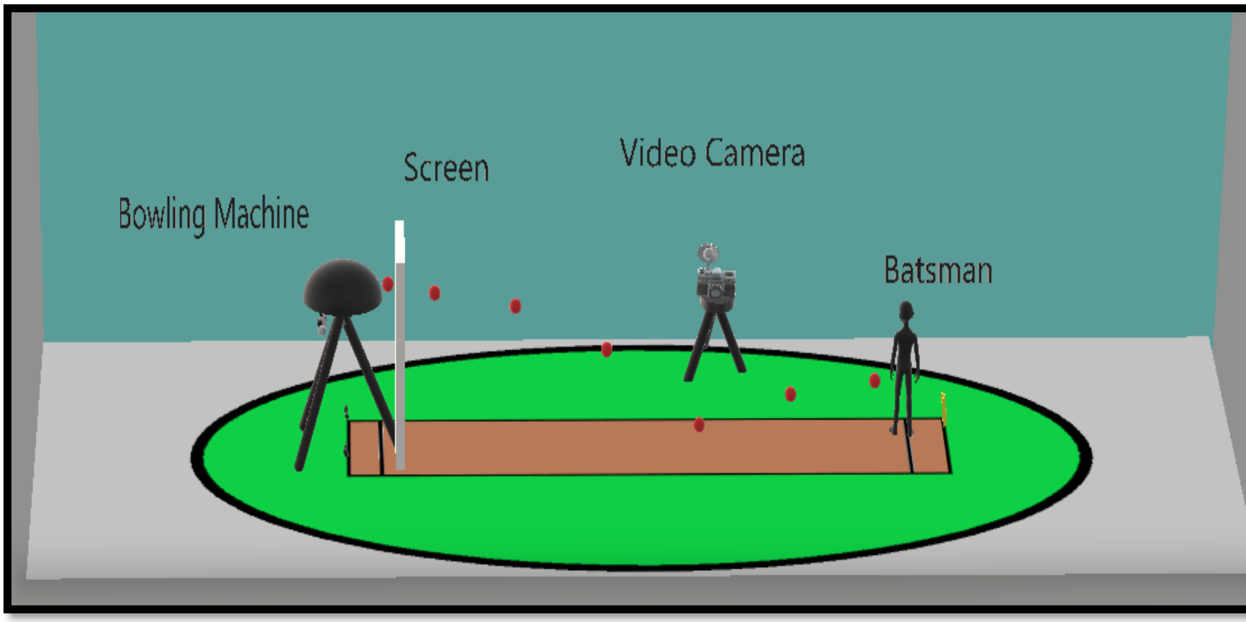
Appendices

Appendix 1- Setup of the testing procedure



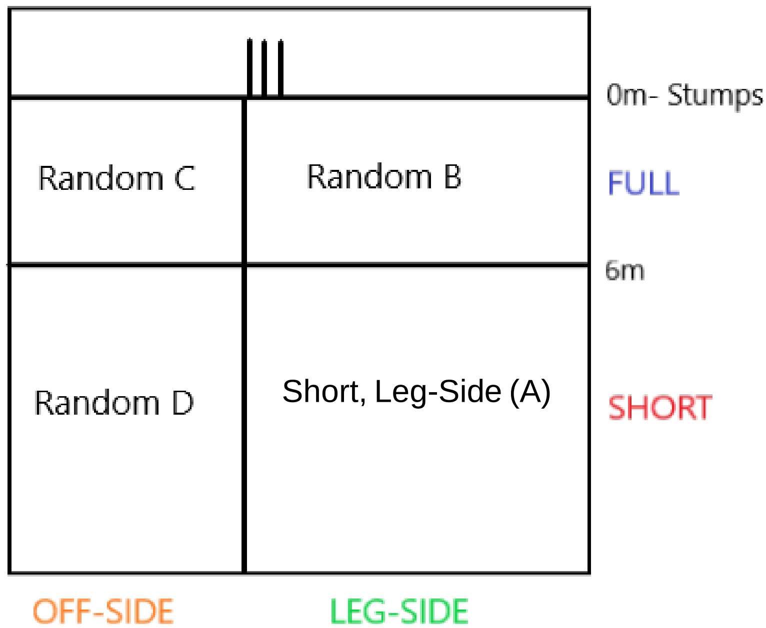
Appendix 2- Completed sequencing of deliveries and field placements

Over	Bowler	Ball	Combo	Field placement	Actual Delivery
1	1	1	Combo 2	1	Full, Leg-Side
		2	Combo 4	2	Short, Off-Side
		3	Combo 1	1	Short, Leg-Side
		4	Combo 3	3	Full, Off-Side
		5	Combo 4	4	Short, Off-Side
		6	Combo 2	1	Full, Leg-Side
2	2	7	Combo A	1	Short, Leg-Side
		8	Combo D	3	Short, Leg-Side
		9	Combo A	1	Short, Leg-Side
		10	Combo D	4	Short, Leg-Side
		11	Combo A	1	Short, Leg-Side
		12	Combo B	1	Full, Off-Side
3	1	13	Combo 3	3	Full, Off-Side
		14	Combo 2	1	Full, Leg-Side
		15	Combo 3	2	Full, Off-Side
		16	Combo 1	1	Short, Leg-Side
		17	Combo 2	1	Full, Leg-Side
		18	Combo 4	4	Short, Off-Side
4	2	19	Combo B	1	Short, Off-Side
		20	Combo A	1	Short, Leg-Side
		21	Combo C	4	Full, Off-Side
		22	Combo D	2	Short, Leg-Side
		23	Combo C	2	Full, Leg-Side
		24	Combo D	3	Short, Leg-Side
5	1	25	Combo 4	3	Short, Off-Side
		26	Combo 3	4	Full, Off-Side
		27	Combo 2	1	Full, Leg-Side

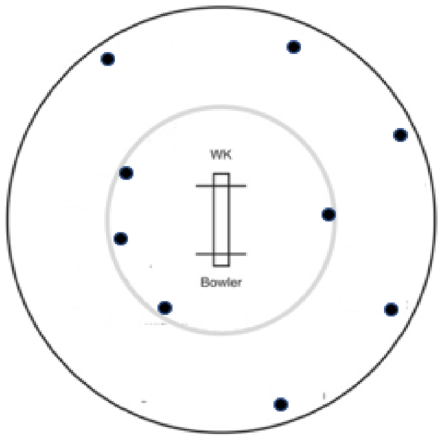
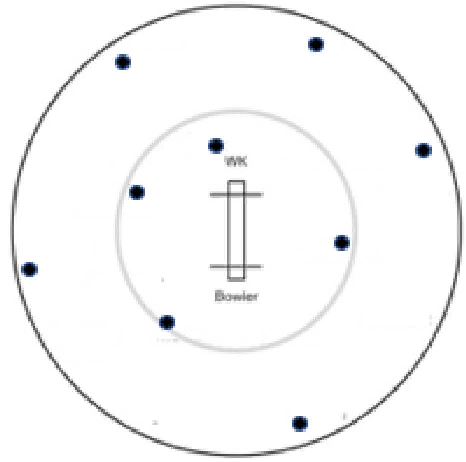
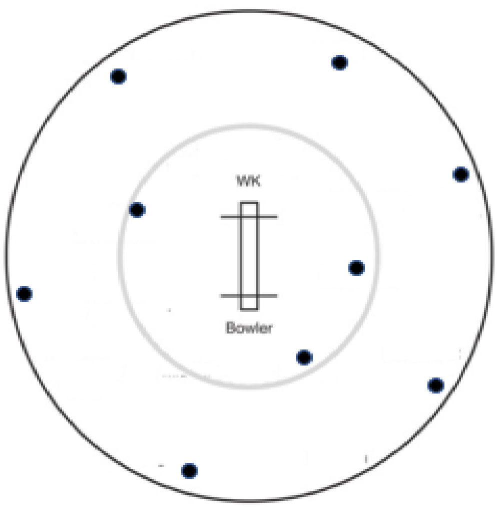
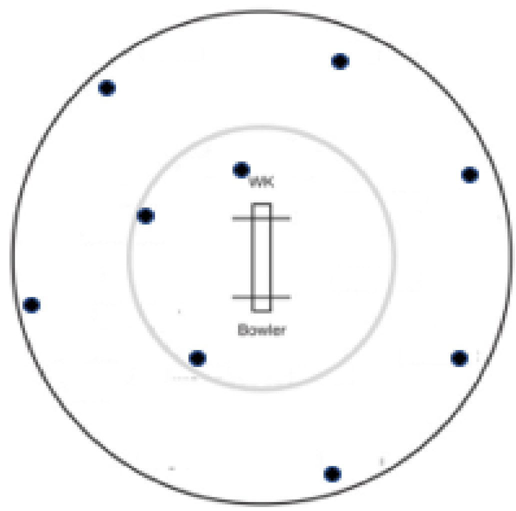
		28	Combo 3	2	Full, Off-Side
		29	Combo 3	4	Full, Off-Side
		30	Combo 1	1	Short, Leg-Side
6	2	31	Combo A	1	Short, Leg-Side
		32	Combo D	4	Short, Leg-Side
		33	Combo B	1	Full, Leg-Side
		34	Combo C	3	Full, Off-Side
		35	Combo D	2	Short, Leg-Side
		36	Combo A	1	Short, Leg-Side
7	1	37	Combo 2	1	Full, Leg-Side
		38	Combo 1	1	Short, Leg-Side
		39	Combo 4	2	Short, Off-Side
		40	Combo 1	1	Short, Leg-Side
		41	Combo 3	4	Full, Off-Side
		42	Combo 4	3	Short, Off-Side
8	2	43	Combo B	1	Short, Off-Side
		44	Combo D	4	Short, Leg-Side
		45	Combo A	1	Short, Leg-Side
		46	Combo C	2	Full, Leg-Side
		47	Combo A	1	Short, Leg-Side
		48	Combo B	1	Short, Off-Side
9	1	49	Combo 4	3	Short, Off-Side
		50	Combo 2	1	Full, Leg-Side
		51	Combo 3	2	Full, Off-Side
		52	Combo 1	1	Short, Leg-Side
		53	Combo 4	3	Short, Off-Side
		54	Combo 1	1	Short, Leg-Side
10	2	55	Combo B	1	Short, Off-Side
		56	Combo D	2	Short, Leg-Side
		57	Combo A	1	Short, Leg-Side

		58	Combo D	4	Short, Leg-Side
		59	Combo D	3	Short, Leg-Side
		60	Combo C	2	Full, Leg-Side
11	1	61	Combo 4	2	Short, Off-Side
		62	Combo 2	1	Full, Leg-Side
		63	Combo 1	1	Short, Leg-Side
		64	Combo 2	1	Full, Leg-Side
		65	Combo 3	4	Full, Off-Side
		66	Combo 1	1	Short, Leg-Side
12	2	67	Combo A	1	Short, Leg-Side
		68	Combo D	3	Short, Leg-Side
		69	Combo A	1	Short, Leg-Side
		70	Combo C	3	Full, Off-Side
		71	Combo A	1	Short, Leg-Side
		72	Combo D	4	Short, Leg-Side

Appendix 3- Pitch Map indicating different possible landing positions of each delivery



Appendix 4- Field placements presented to batsmen prior to each delivery

FIELD 1 (RHB)- Suggests Short, Legside Delivery	FIELD 2 (RHB)- Random
	
FIELD 3 (RHB)- Random	**FIELD 4 (RHB)- Random**
	

Appendix 5- Data collection sheet used during

Over	Ball	Field Placing	Actual Delivery		Prediction Accuracy				Response Accuracy	Sources used?	Other?
			Length	Line	Length	Line	Correct/ Incorrect	Certainty	Successful/ Unsuccessful		
			Short/ Full	Offside/ Legside	S=short; F=Full	O=Offside; L=Legside	0= Incorrect; 1= Correct	**1-** Not at all certain **2-** Slightly certain **3-** Somewhat certain **4-** Moderately certain **5-** Extremely certain	0= Unsuccessful; 1= Successful		
1	1	Fielld Placing 1	Short	Offside							
	2	Fielld Placing 3	Full	Offside							
	3	Fielld Placing 2	Short	Legside							
	4	Fielld Placing 4	Short	Legside							
	5	Fielld Placing 2	Full	Legside							
	6	Fielld Placing 1	Full	Offside							

Appendix 6- Informed consent form

NELSON MANDELA UNIVERSITY

INFORMATION AND INFORMED CONSENT FORM

RESEARCHER'S DETAILS	
Title of the research project	Interaction between situational probability information for cricket batsman when anticipating bowler's intentions
Reference number	
Principal investigators	**Joshua du Preez**
Address	**30 Arkhon Street, Summerstrand, Port Elizabeth**
Postal Code	**6001**
Contact telephone number (private numbers not advisable)	**041 504 2518 (Ryan Raffan)**

A. DECLARATION BY OR ON BEHALF OF PARTICIPANT		Initial
I, the participant and the undersigned	(full names)	
ID number		
OR		
I, in my capacity as	(parent or guardian)	
of the participant	(full names)	
ID number		
Address (of participant)		

A.1 HEREBY CONFIRM AS FOLLOWS:		Initial
I, the participant, was invited to participate in the above-mentioned research project		
that is being undertaken by	Joshua du Preez	
from	The faculty of Health Sciences	
of the Nelson Mandela University.		

THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT:					Initial
2.1	**Aim:**	To investigate the interaction between two sources of situational probability (field placement and action preferences of bowlers) used by near-expert cricket batsmen to anticipate the bowler's intention.			
2.2	**Procedures:**	Participants will be required to face 72 deliveries (12 overs) bowled by a bowling machine and predict, via verbal report, the type of each delivery.			
2.3	**Risks:**	The risk of this testing procedure is low as participants will be required to wear full protective gear			
2.4	**Possible benefits:**	As a result of my participation in this study could help me develop my anticipatory skills			
2.5	**Confidentiality:**	My identity will not be revealed in any discussion, description or scientific publications by the investigators.			
2.6	**Access to findings:**	Any new information or benefit that develops during the course of the study will be shared verbally to me as an individual or to the coach as a group			
2.6	**Voluntary participation / refusal / discontinuation:**	My participation is voluntary	YES		
		My decision whether or not to participate will in no way affect my present or future care / employment / lifestyle	TRUE		

3. THE INFORMATION ABOVE WAS EXPLAINED TO ME/THE PARTICIPANT BY:									Initial
Joshua du Preez									
in	**Afrikaans**		**English**		**Xhosa**		**Other**		
and I am in command of this language, **or** it was satisfactorily translated to me by									
(Not applicable)									
I was given the opportunity to ask questions and all these questions were answered satisfactorily.									

4.	No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation.	
5.	Participation in this study will not result in any additional cost to myself.	

A.2 I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT:			
Signed/confirmed at		on	20
Signature or right thumb print of participant	Signature of witness:		
	Full name of witness:		

STATEMENT BY OR ON BEHALF OF INVESTIGATOR(S)									
I,	Joshua du Preez			declare that:					
1.	I have explained the information given in this document to								
	and / or her representative								
2.	She was encouraged and given ample time to ask me any questions;								
3.	This conversation was conducted in	**Afrikaans**		**English**		**Xhosa**		**Other**	
	And no translator was used <u>OR</u> this conversation was translated into								
	(language)	by	(Not applicable)						
4.	I have detached Section D and handed it to the participant		YES		NO				
Signed/confirmed at		on	20						
Signature of interviewer	Signature of witness:								
	Full name of witness:								

IMPORTANT MESSAGE TO PATIENT/REPRESENTATIVE OF PARTICIPANT

Dear participant/representative of the participant Thank you for your participation in this study. Should, at any time during the study: - an emergency arise as a result of the research, or - you require any further information with regard to the study, or	
Kindly contact	Mr Ryan Raffan
at telephone number	(041 504 2518)